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Clay**

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(54) **RELEVATOR, RELEVATOR SYSTEM, AND  
METHOD OF USING A RELEVATOR**

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*Primary Examiner* — Tien Dinh

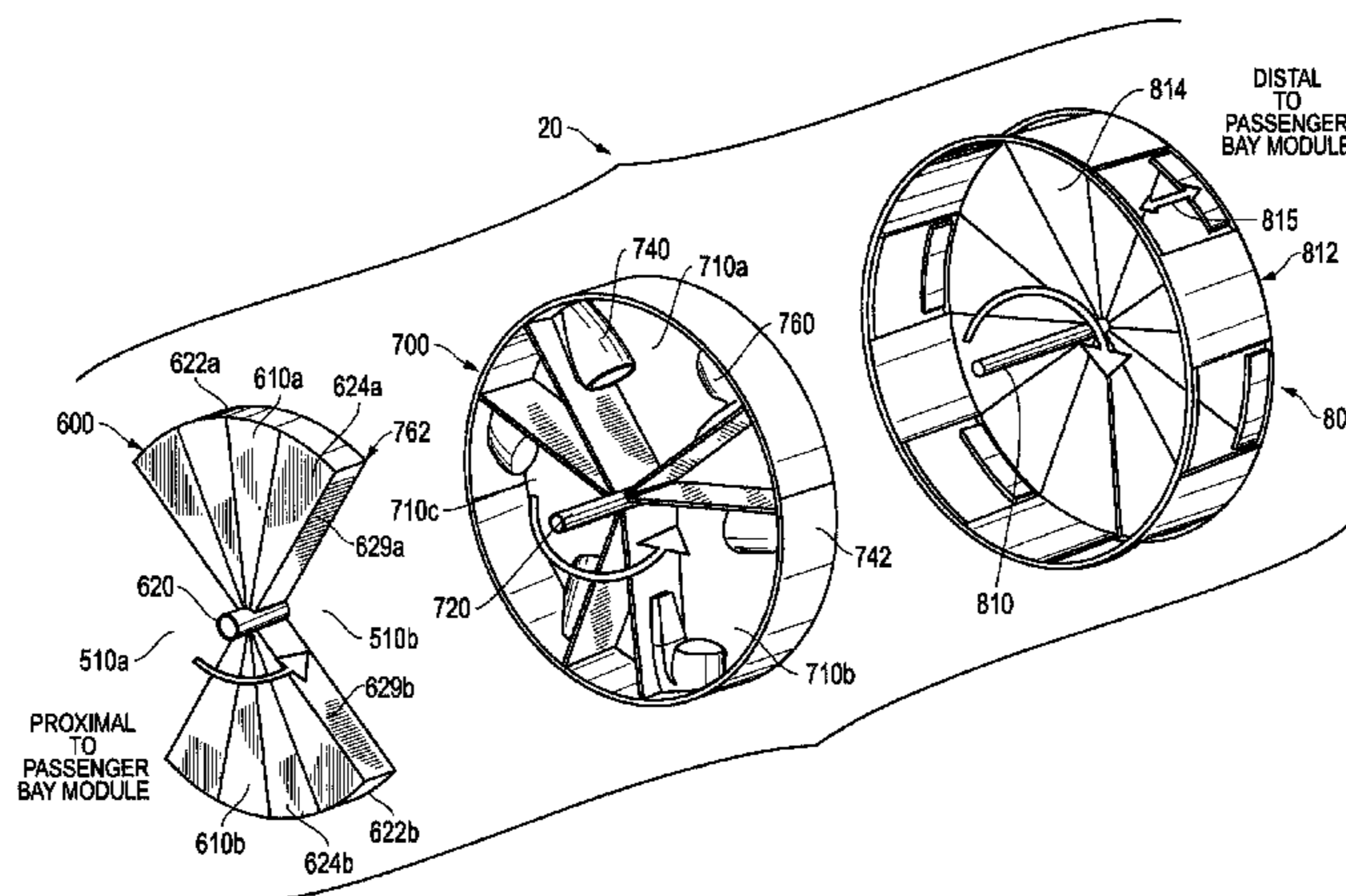
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(57) **ABSTRACT**

A space relevator adapted to transition an object between a stationary compartment and a rotating module rotating in a first direction, the relevator comprising: a relevator module comprising a plurality of substantially solid pie-shaped structures separated by a plurality of pie-shaped compartments all positioned around a central axis; a relevator central shaft extending along the central axis; the relevator module being adapted to receive a rotate signal and a stop signal, one or more of the pie-shaped compartments comprising an entry between the stationary compartment and the rotating module when the relevator module receives a stop signal and after the relevator module receives a rotate signal.

**24 Claims, 13 Drawing Sheets**



**Related U.S. Application Data**

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*B64G 1/50* (2006.01)
- (52) **U.S. Cl.**  
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- (58) **Field of Classification Search**  
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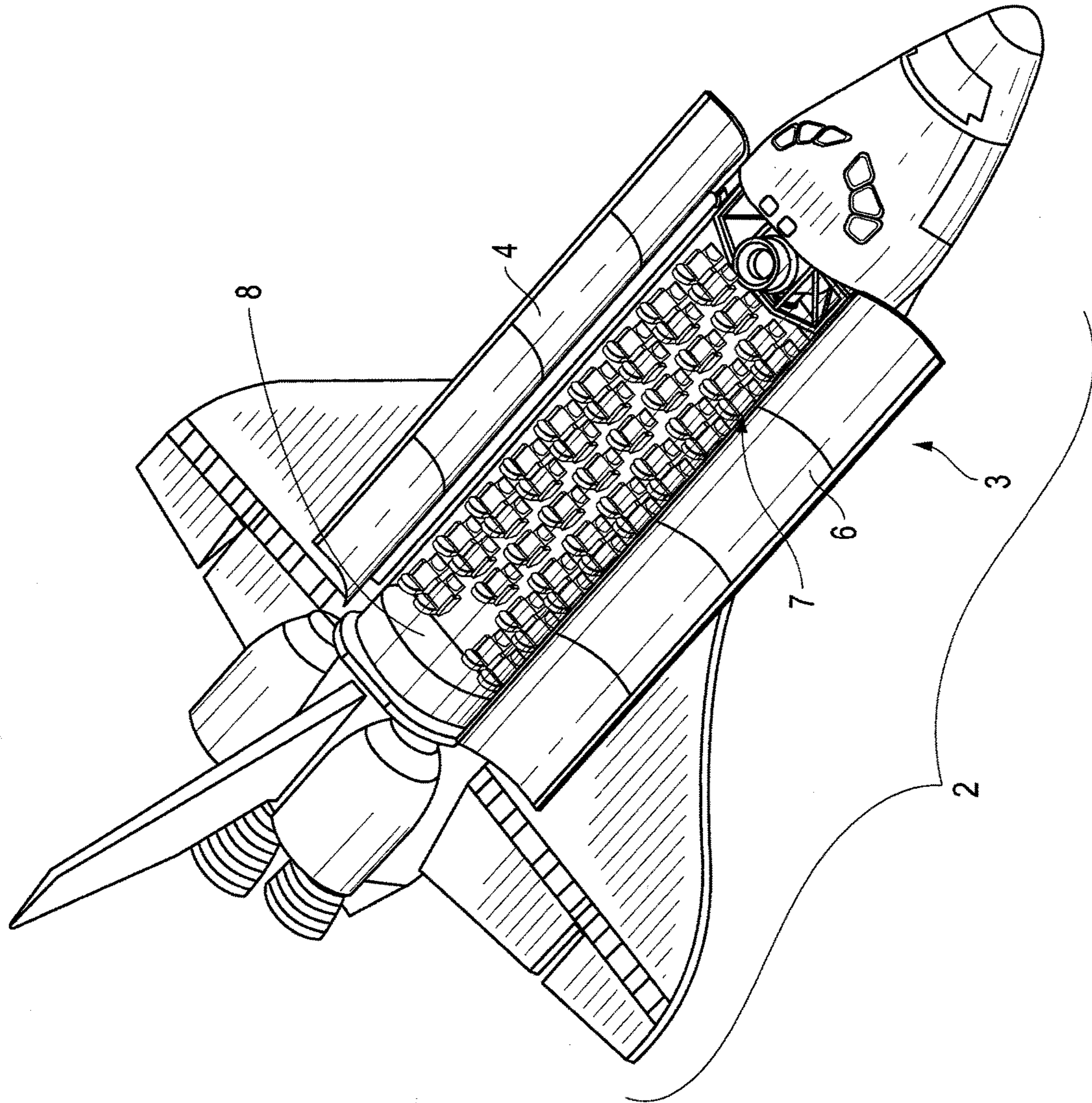


FIG. 1

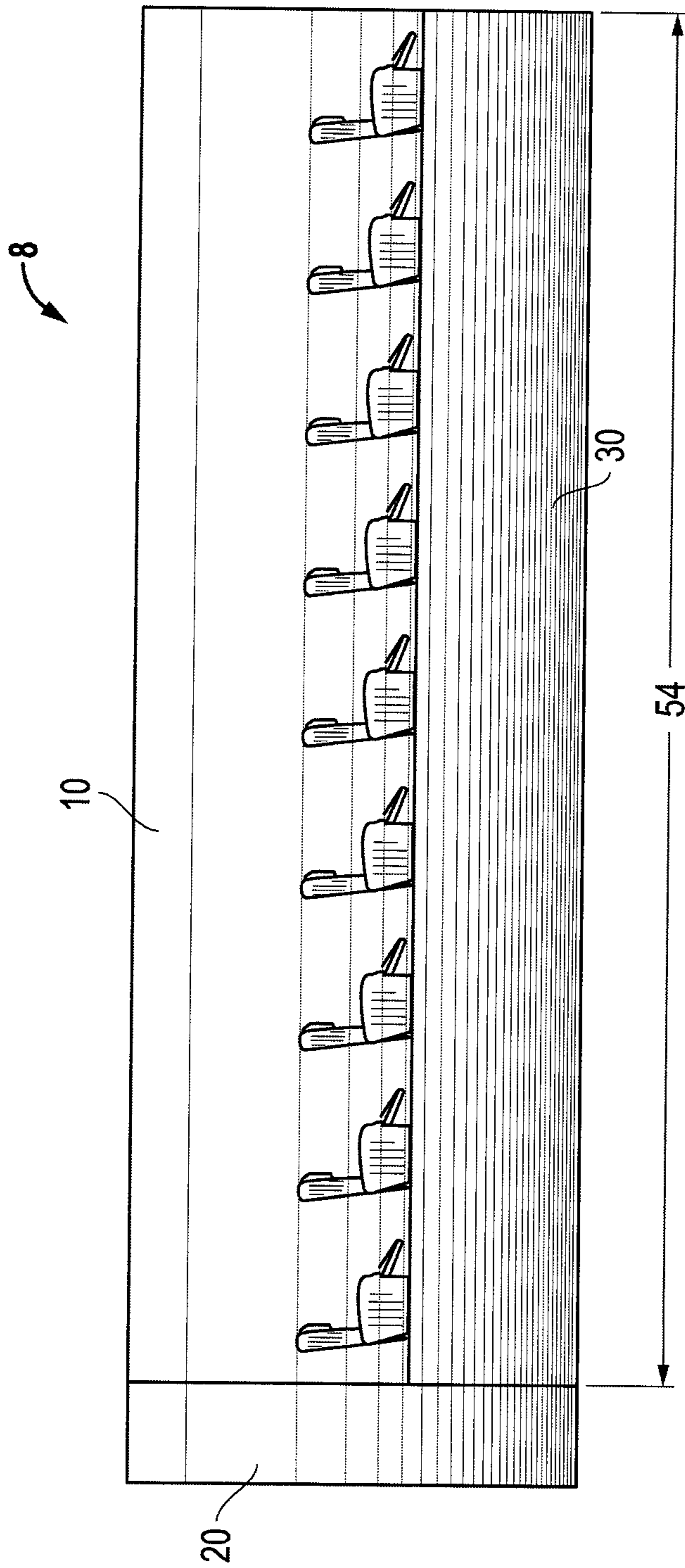


FIG. 2

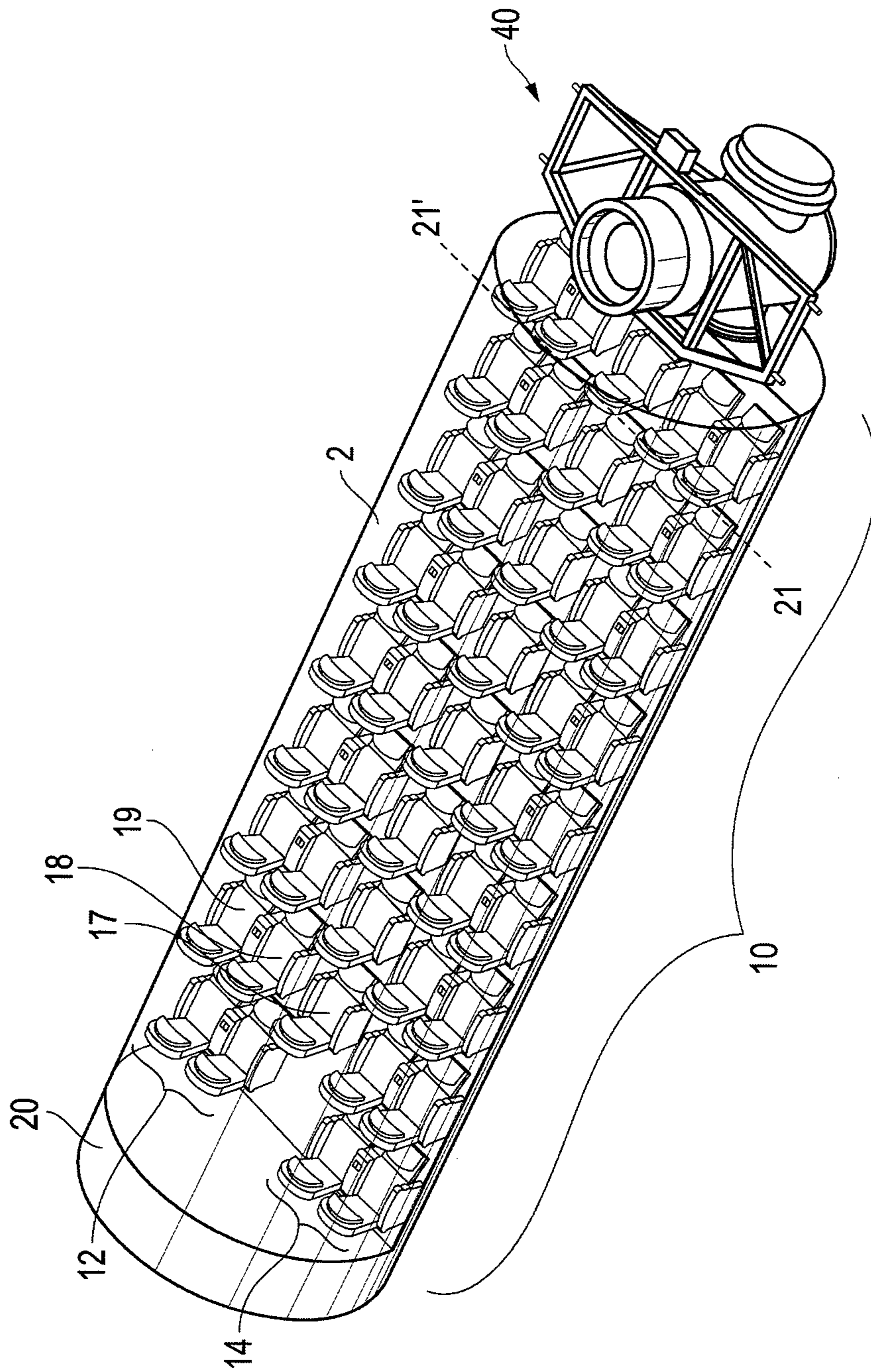


FIG. 3

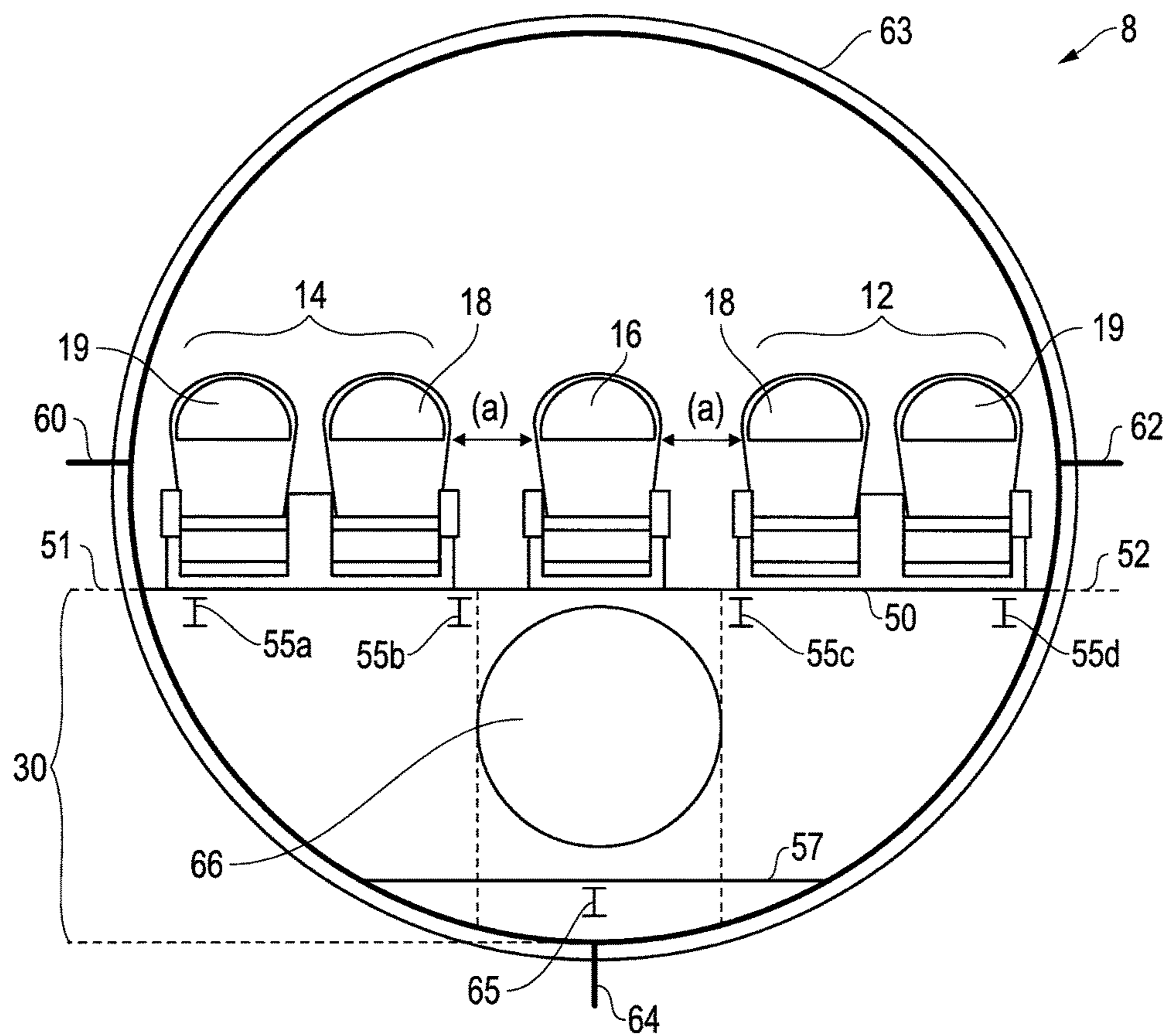


FIG. 4

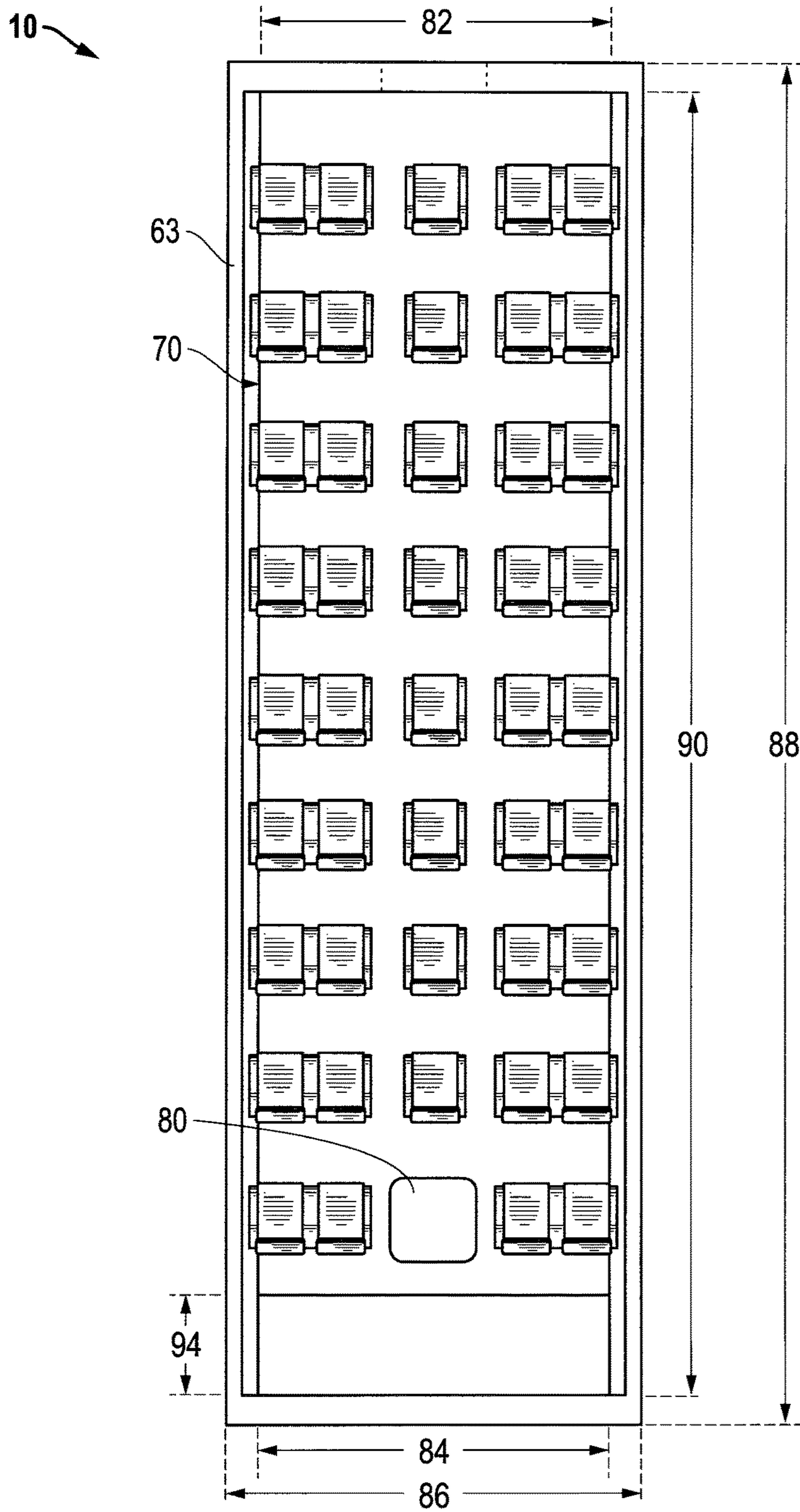


FIG. 5



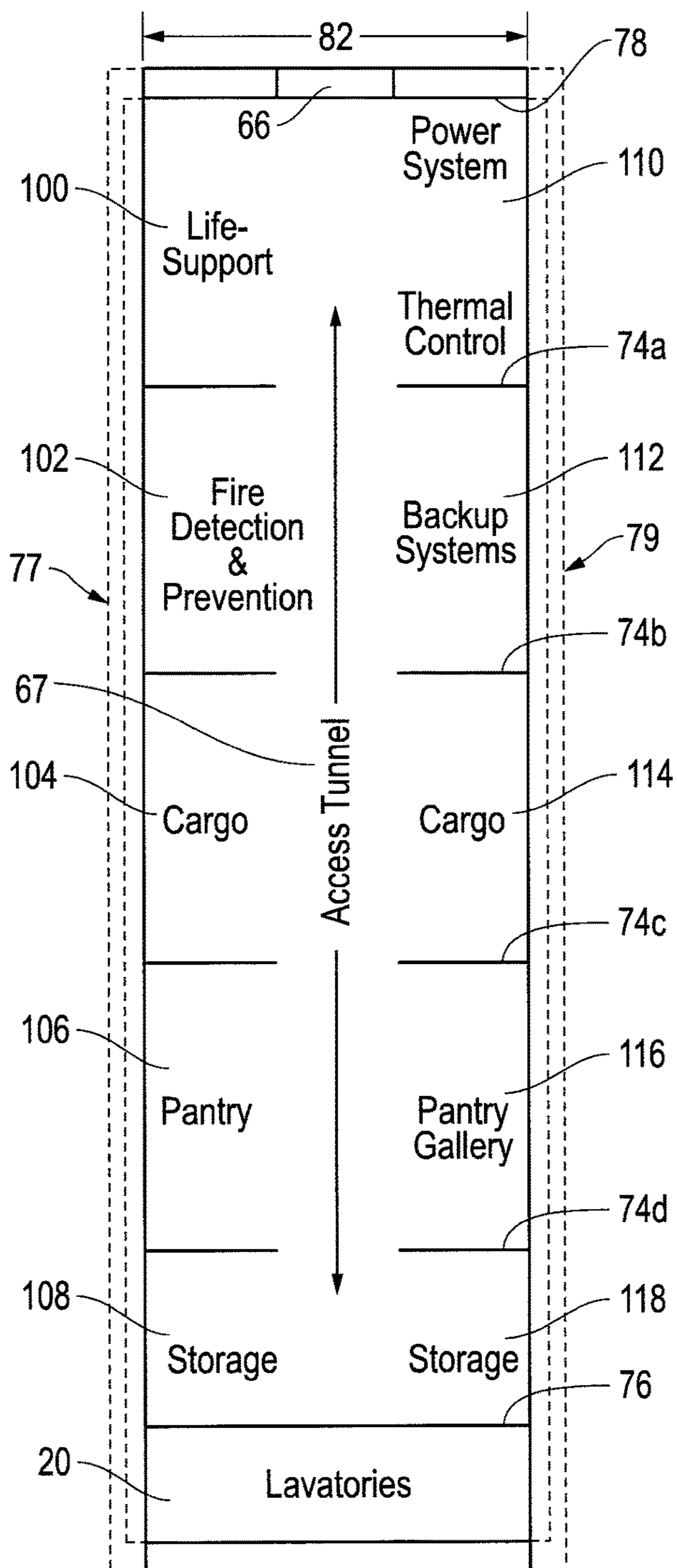


FIG. 6

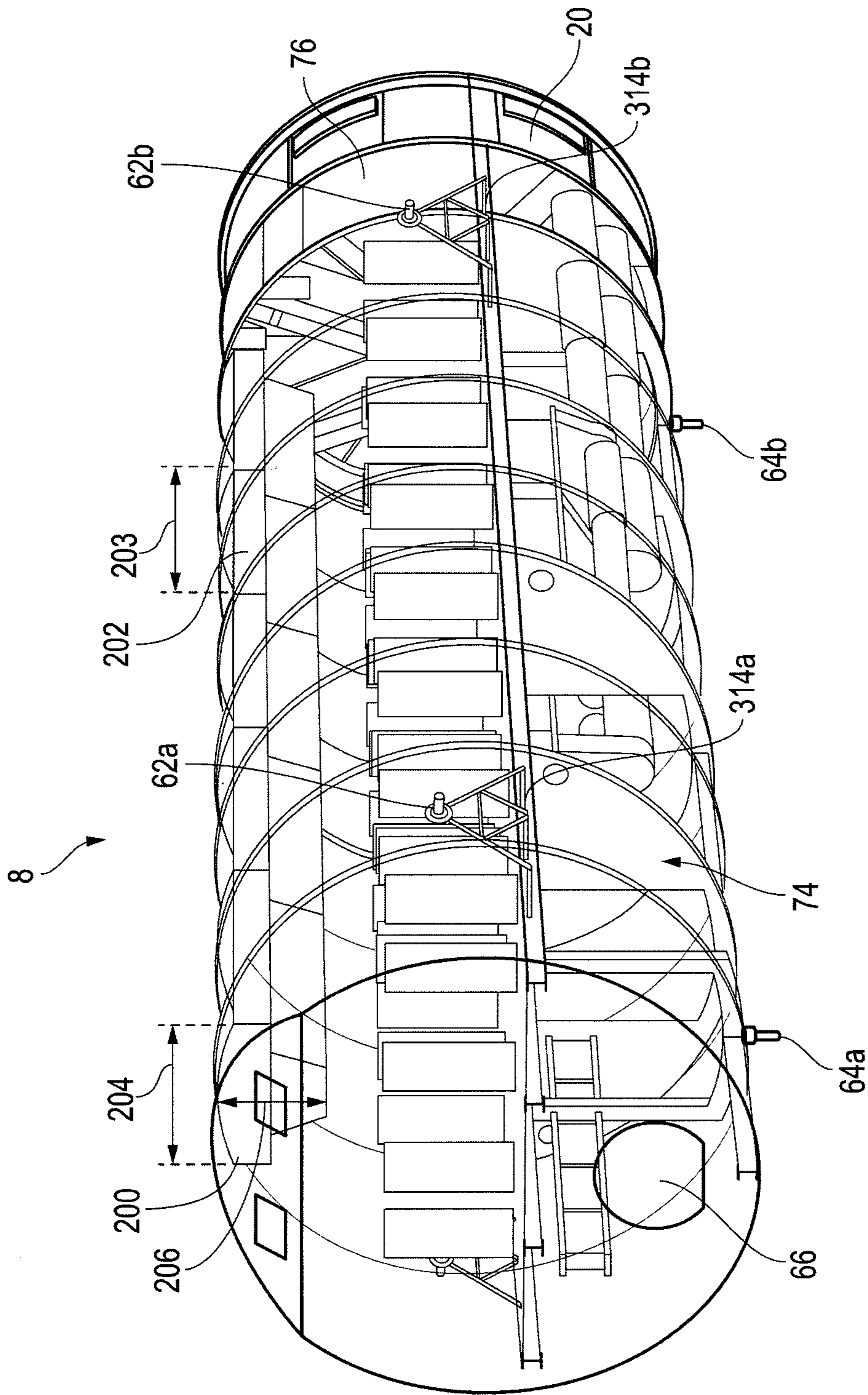


FIG. 7

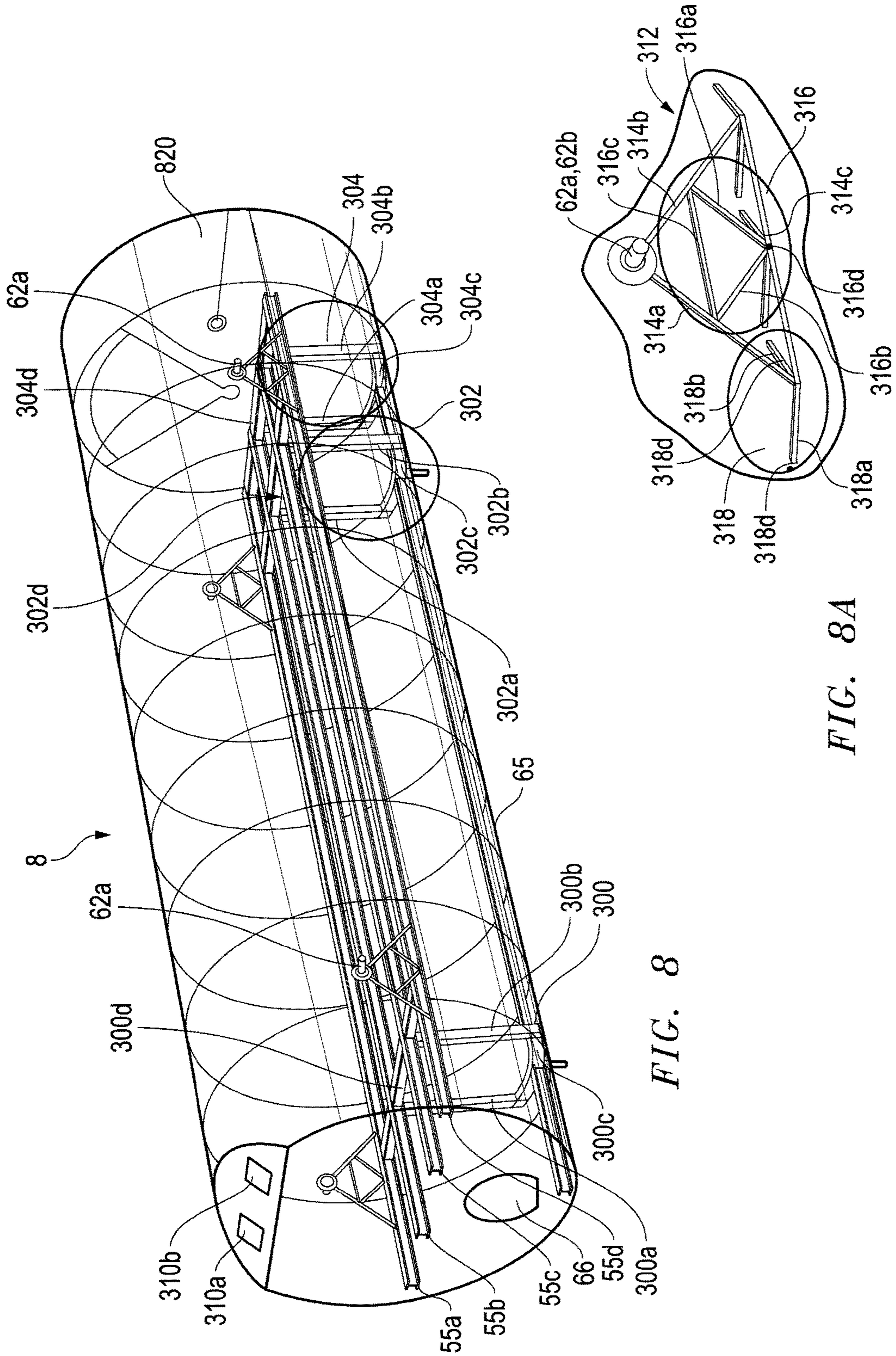


FIG. 8

FIG. 8A

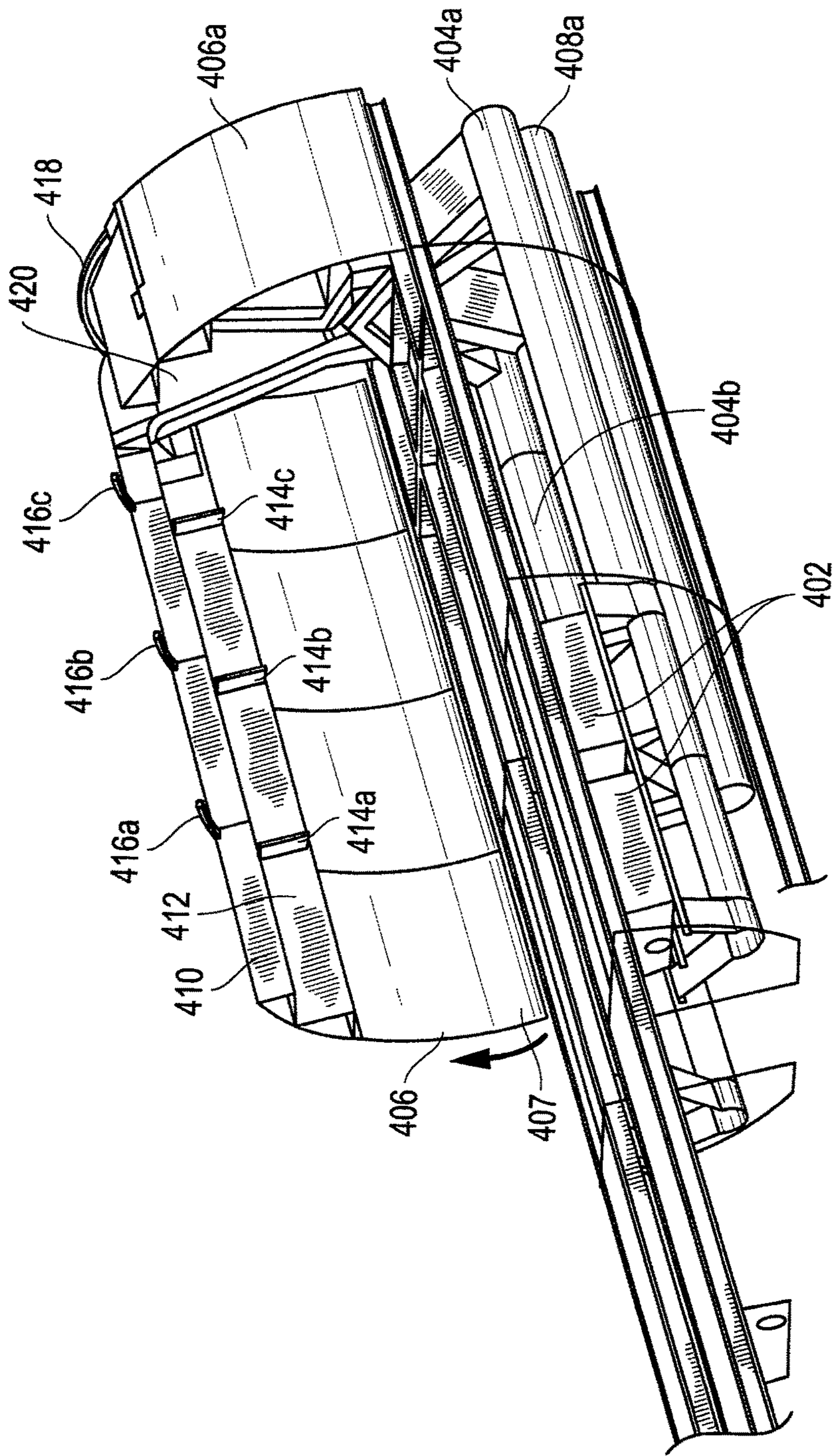


FIG. 9

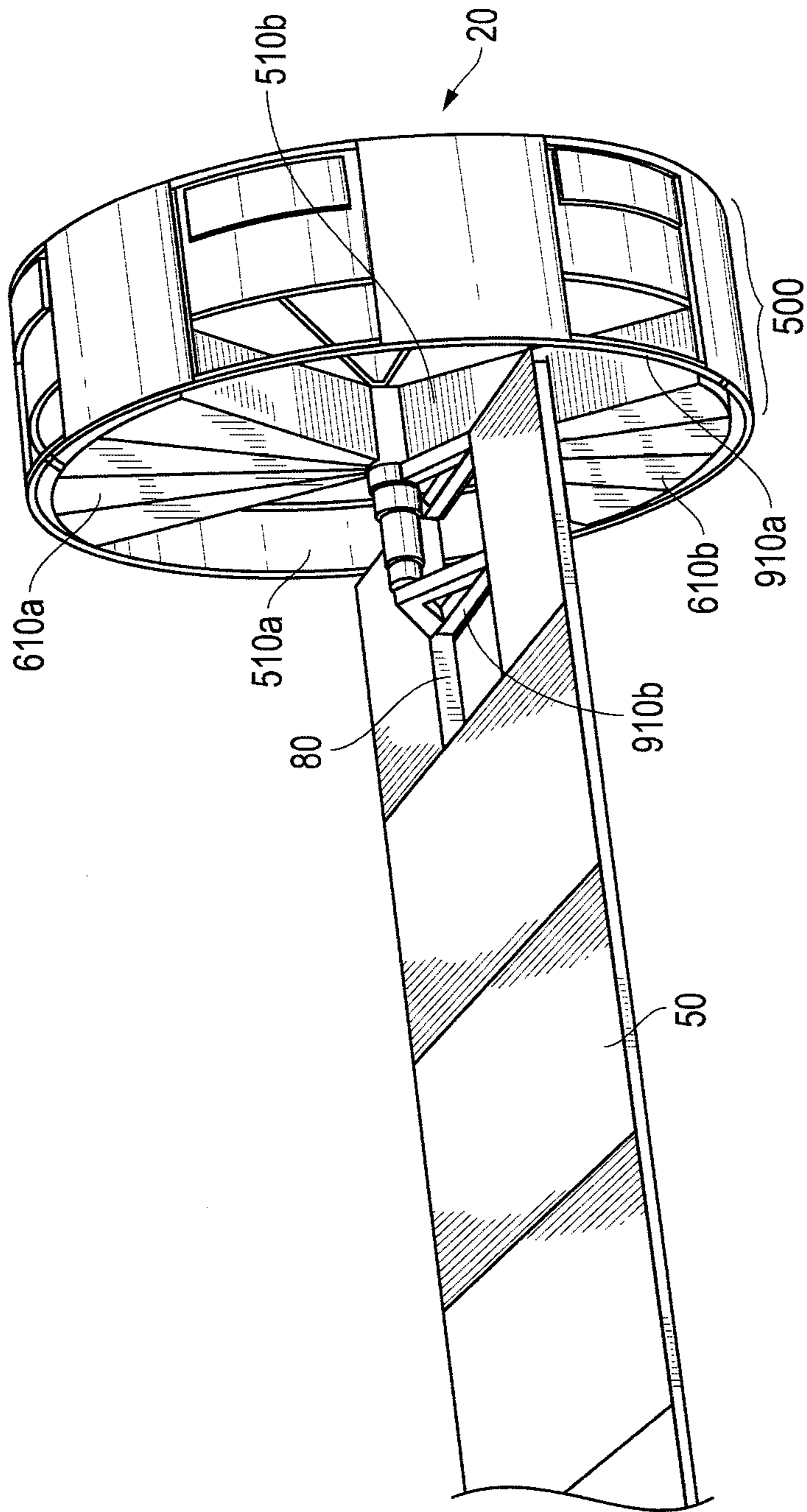
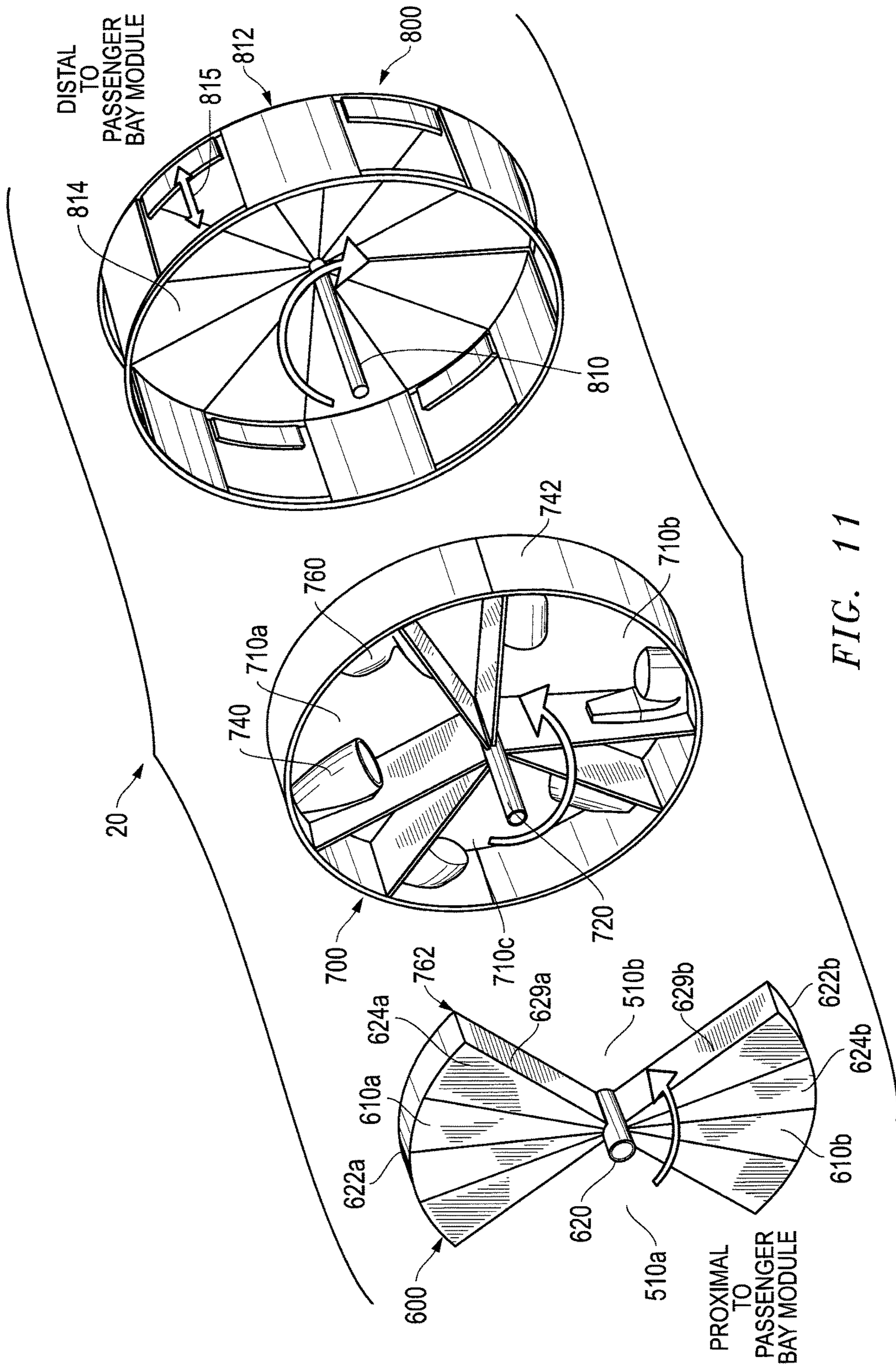


FIG. 10



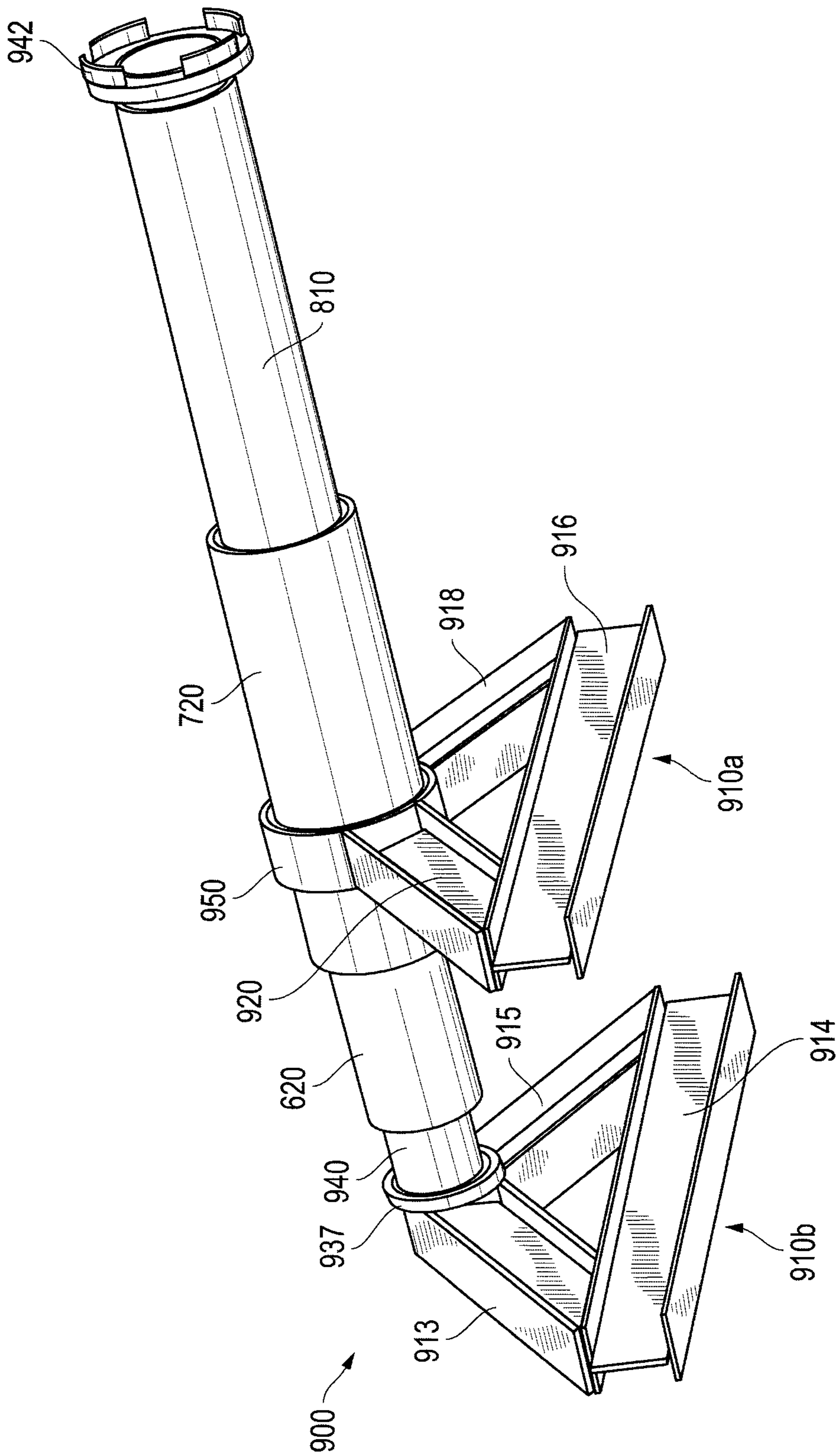


FIG. 12

System	Component	Item Weight (lbs.)	Count	Weight (lbs.)
Structure and Pressure vessel				
	Al-Li Panels	1346.95	10	13469.5
	Al-Li End cap	1131.275	2	2262.55
	Al I-beams	211.05	4	844.2
	Vertical I-beams	75.04	4	300.16
	Ti Longeron bracket	450	4	1800
	Ti Keel trunnion	50	2	100
	Beta Cloth	100	11	1100
	ODS Door	250	1	250
	Insulation	100	11	1100
	Bulkheads	502.79	3	1508.37
	Lav bulkhead	754.18	1	754.18
Compartment 1- Above deck				
	Floor panels	376.65	9	3389.85
	Seats	65	44	2860
	Ducting	110	9	990
Compartment 2- Below deck				
	Batteries	100	5	500
	ECLSS	140	8	1120
	Ducting	110	4	440
	Gallery	500	1	500
Compartment 3- Lavatories				
	Relavator	600	1	600
	Lavatory	1200	1	1200
	Counter Weight	800	1	800
	Electric motors	50	3	150
Compartment 4- Sleeper Cabins				
	Cabins	150	5	750
Dry Mass				36788.81
Passengers		250	44	11000
Water		1100	1	1100
Total Weight				48888.81

FIG. 13



## RELEVATOR, RELEVATOR SYSTEM, AND METHOD OF USING A RELEVATOR

This application is a divisional of U.S. patent application Ser. No. 13/669,385, filed Nov. 5, 2012 (pending), which claims the benefit of Provisional Application No. 61/556,212, filed Nov. 5, 2011, each of which is incorporated herein by reference.

### FIELD OF THE INVENTION

The present application relates to a relevator, a relevator system, and a method of using a relevator adapted to transition an object between a stationary compartment and a rotating module rotating in a first direction. The relevator of the present application may be used in a variety of applications.

### BACKGROUND

In one embodiment, described in detail herein, the relevator is a component of a Space Shuttle Program (“SSP”) Orbital Vehicle. The SSP was a manned orbital rocket and spacecraft system (a “SSP system”) operated by National Aeronautics and Space Administration (NASA) on well over 100 missions from 1981 to 2011. The SSP combined rocket launch, orbital spacecraft, and re-entry spaceplane with modular add-ons.

### BACKGROUND

In one embodiment, described in detail herein, the relevator is a component of a Space Shuttle Program (“SSP”) Orbital Vehicle. The SSP was a manned orbital rocket and spacecraft system (a “SSP system”) operated by National Aeronautics and Space Administration (NASA) on well over 100 missions from 1981 to 2011. The SSP combined rocket launch, orbital spacecraft, and re-entry spaceplane with modular add-ons.

### SUMMARY OF THE INVENTION

A space relevator adapted to transition an object between a stationary compartment and a rotating module rotating in a first direction, the relevator comprising: a relevator module comprising a plurality of substantially solid pie-shaped structures separated by a plurality of pie-shaped compartments all positioned around a central axis; a relevator central shaft extending along the central axis; the relevator module being adapted to receive a rotate signal and a stop signal, one or more of the pie-shaped compartments comprising an entry between the stationary compartment and the rotating module when the relevator module receives a stop signal and after the relevator module receives a rotate signal.

A relevator system adapted to transition an object between a stationary compartment and a rotating module, the relevator system comprising: the rotating module comprising a substantially cylindrical module adapted to rotate in a first direction around a central shaft extending along a central axis of the substantially cylindrical module at a speed that would be sufficient to produce centrifugal force in the rotating module to replicate gravity; a relevator module comprising a plurality of substantially solid pie-shaped structures separated by a plurality of pie-shaped compartments adapted to rotate around the central shaft in the first direction, the relevator module being adapted to receive a rotate signal and a stop signal, one or more of the pie-shaped

compartments comprising an entry between the stationary compartment and the rotating module when the relevator module receives a stop signal and after the relevator module receives a rotate signal; wherein the relevator system comprises a substantially cylindrical counterweight compensator adapted to rotate around the central shaft in a direction opposite the first direction, the counterweight compensator comprising a counterweight distal wall extending from the central shaft to a circumference of the substantially cylindrical counterweight, the counterweight distal wall being independently rotatable relative to a distal wall of the rotating module.

A method of using a relevator to transition an object between a stationary compartment and a rotating module rotating in a first direction, the method comprising: providing as the rotating module a substantially cylindrical module adapted to rotate in the first direction around a central shaft extending along a central axis of the substantially cylindrical module at a speed that would be sufficient to produce centrifugal force in the rotating module to replicate gravity; providing as the relevator a substantially cylindrical relevator module comprising a plurality of pie-shaped solid structures alternating with a plurality of pie-shaped compartments, the relevator module being adapted to rotate around the central shaft adapting the relevator module to receive a rotate signal and a stop signal, one or more of the pie-shaped compartments of the relevator module comprising an entry between the stationary compartment and the relevator module after the relevator module receives a stop signal and after the relevator module receives a rotate signal and the relevator module is rotating at the same speed as the rotating module; transitioning the object from the stationary compartment into the entry; sending the rotate signal to the relevator module to rotate the relevator module in the first direction until the relevator module is rotating at the same speed as the rotating module; and, transitioning the object from the entry into the rotating module.

### BRIEF DESCRIPTION OF THE DRAWINGS

In the following Figures, like parts are referred to by like numerals:

FIG. 1 is a perspective view of the SSP system, with an open payload bay loaded with a cylindrical casing comprising an embodiment of a passenger bay module.

FIG. 2 is a schematic side view of a portion of the cylindrical casing comprising a passenger bay model and a lavatory module.

FIG. 3 is a top perspective view of the cylindrical casing enclosed in what appears as a semi-transparent shell structure.

FIG. 4 is a cross section taken along line 21-21' of FIG. 3.

FIG. 5 is a schematic plan view looking down at an embodiment of the passenger bay module.

FIG. 6 is a schematic view looking down at an embodiment of a service galley module.

FIG. 7 is a port frontal perspective schematic view of the cylindrical casing.

FIG. 8 is a port frontal perspective view of the cylindrical casing containing only the structural support.

FIG. 8a is a perspective view of a support scaffold adapted to support the cylindrical casing in Longeron attachment mechanisms.

FIG. 9 is a cut away view of a portion of the distal end including the Environmental Control and Life Support System components and a stationary lavatory entrance zone.

FIG. 10 is a perspective view of the floor of the passenger bay module and the attached lavatory module.

FIG. 11 is an expanded view of the lavatory module.

FIG. 12 is a perspective view of a lavatory drive shaft assembly.

FIG. 13 is a chart giving the mass estimate results from Example 1.

#### DETAILED DESCRIPTION

In one embodiment, the releveator of the present application is a component of a Space Shuttle Program (SSP) Orbital vehicle. In one embodiment, the SSP comprises a payload bay comprising a passenger bay module adapted to provide and maintain habitable conditions for twenty or more passengers during a mission traveling from earth to space and back to earth.

The SSP

Upon launch, the SSP generally comprises: an SSP Orbital Vehicle; one or more recoverable rocket boosters; one or more external propellant tanks; a payload bay; and supporting infrastructure. The general structure of components of the SSP are known (reference Wikipedia description of the SSP at Ex. A, incorporated herein by reference). In one embodiment, the SSP complies with NSTS 07700, Volume I, Revision G, Dec. 17, 1997 (Ex. B, incorporated herein by reference).

The SSP Orbital Vehicle is a type of reusable winged "space-plane." In one embodiment, the SSP Orbital Vehicle resembles a conventional aircraft. In one embodiment, the SSP Orbital Vehicle carries crews and payloads into low Earth orbit. In one embodiment, the SSP Orbital Vehicle is adapted to safely re-enter the earth's atmosphere. In one embodiment, the SSP Orbital Vehicle is adapted to land safely at a location on earth.

In one embodiment, the SSP Orbital Vehicle is adapted to land as a glider. A glider is a heavier-than-air craft that is supported in flight by the dynamic reaction of the air against its lifting surfaces. Free flight of a glider does not depend on an engine.

The Payload Bay

Referring to FIG. 1, the SSP Orbital Vehicle 2 comprises a fuselage 3 comprising a payload bay 7. As seen in FIG. 1, the SSP Orbital Vehicle generally comprises an opening through the top of the SSP Orbital Vehicle 2 for loading the payload bay 7. In one embodiment, the SSP Orbital Vehicle 2 comprises opposed hinged doors 4, 6 that open to load the payload bay 7.

The Cylindrical Casing

In one embodiment, the present application provides a cylindrical casing adapted to be loaded into a payload bay of a Space Shuttle Program (SSP) Orbital Vehicle. In one embodiment, the cylindrical casing is adapted to transport and maintain habitable conditions for twenty or more passengers during a mission. In one embodiment, the cylindrical casing is loaded into a SSP Orbital Vehicle. In one embodiment, the application provides a method of using the SSP Orbital Vehicle comprising a payload bay loaded with the cylindrical casing.

In one embodiment, referring to FIG. 4, the cylindrical casing 59 comprises any strong, lightweight, flexible metal, combination of metals, or carbon composite material, capable of withstanding substantial pressure. In one embodiment the cylindrical casing 59 comprises a material selected from the group consisting of aluminum, a blend of aluminum-lithium, and carbon composite. Suitable cylindrical casings include, for example, pressure vessels. Suitable

pressure vessels are commercially available from a variety of sources, for example, Amalga Composite, Inc. of West Allis, Wis. and Lockheed Martin of New Orleans, La. In one embodiment, the cylindrical casing 59 comprises 23 pieces of aluminum-lithium, commercially machined by AAR Precision Systems of Huntsville, Ala. In one embodiment, the cylindrical casing 59 is welded by Lockheed Martin of New Orleans, La.

In one embodiment, the cylindrical casing 8 comprises an Orbital Docking Port System (ODS) comprising one or more orbital docking port (ODP) at a proximal end, a lavatory module at a distal end, and a passenger bay module extending between the ODP and the lavatory module. In one embodiment, the ODS comprises interface connections adapted to mate with receiving connections at the International Space Station. In one embodiment, the ODP provides a pathway for passengers to pass from the SSP Orbital Vehicle and to the International Space Station.

Referring to FIG. 1, in one embodiment, the application provides a cylindrical casing 8 adapted to be loaded into the payload bay 7. In one embodiment, referring to FIG. 2, the cylindrical casing 8 comprises a passenger bay module 10, a service galley module 30, an Orbital Docking Structure (ODS) (40 in FIG. 3) comprising one or more Orbital Docking Ports (ODP) (66 in FIG. 4), and a lavatory module 20.

In one embodiment, referring to FIG. 4, the cylindrical casing 8 comprises a plurality of external attachment trunnions. In one embodiment, the external attachment trunnions meet the specifications in the Shuttle Orbiter/Cargo Standard Interfaces (CORE), ICD-2-19001, Revision L, prepared by Boeing North American, Inc. (incorporated herein by reference). In one embodiment, the dimensions of the external attachment trunnions are adapted to mate with the Longeron attachment mechanisms in the payload bay 7. Longeron attachment mechanisms are depicted in the CORE, ICD-2-19001, Revision L, document at pages 3C-15 through 3C-17.

The external attachment trunnions may be made of a variety of metals or carbon composites. Examples of suitable metals include aluminum, a blend of aluminum and lithium, titanium, or carbon composite. In one embodiment, the external trunnions comprise a blend of aluminum and lithium. Suitable Al—Li is available from Alcoa, Davenport, Iowa.

In the embodiment illustrated in FIG. 4, the cylindrical casing 8 comprises a first lateral attachment trunnion 60 and a second lateral attachment trunnion 62. In one embodiment, referring to FIG. 4, the first attachment trunnion 60 and second attachment trunnion 62 are diametrically opposed to one another along the outer circumference of the cylindrical casing 8. In other words, referring to FIG. 4, a line (a) drawn from the first attachment trunnion 60 to the second attachment trunnion 62 represents the diameter of the cylindrical casing 8. In one embodiment, the cylindrical casing 8 comprises two attachment trunnions on each side of the cylindrical casing. This embodiment is illustrated in FIG. 7, in which attachment trunnions 62a and 62b (FIG. 7) are visible on one side of the cylindrical casing 8.

In one embodiment, referring to FIG. 8a, the external lateral attachment trunnions 62a, 62b (FIG. 8, opposed lateral side not shown) communicate with a scaffold 312. In one embodiment, all of the lateral external attachment trunnions communicate with a scaffold support 312 comprising scaffold beams 314a-c. In one embodiment, the scaffold beams 314a-c form a first isosceles triangle. In one embodiment, first side beams 314a and 314b communicate

## 5

at a 90° angle to form an apex communicating with the external attachment trunnions **62a**, **62b**. In one embodiment, opposed ends of first side beams **314a** and **314b** communicate with a first hypotenuse beam **314c**. In one embodiment, the scaffold support **312** comprises a nested scaffold support **316**. In one embodiment, the nested scaffold support **316** comprises nested scaffold beams **316a-c** forming a second isosceles triangle. In one embodiment, nested side beams **316a** and **316b** communicate at a 90° angle to form an apex **316d** communicating at a midpoint with the first hypotenuse beam **314c**. In one embodiment, opposed ends of second side beams **316a** and **316b** communicate with a second hypotenuse beam **316c**. In one embodiment, the support scaffold **312** also comprises a plurality of lower retainers **318**. In one embodiment, the lower retainers comprise two beams **318** and **318b** extending from an apex **318c** to form a third 90° angle. In one embodiment, opposed ends **318d** of the two beams **318a**, **318b** abut the sheet structure (described below).

In one embodiment, depicted in FIG. 4, the cylindrical casing **8** further comprises one or more keel trunnion **64**. In one embodiment, one or more keel trunnions **64** are radially displaced at an angle of approximately 90° from the first attachment trunnion **60** and the second attachment trunnion **62**. In one embodiment, the cylindrical casing comprises two keel trunnion **64a** and **64b** spaced apart along the bottom of the cylindrical casing **8**. The keel trunnions **64a** and **64b** are adapted to mate with corresponding structure in the payload bay **7**. In one embodiment, the keel trunnions **64a** and **64b** are adapted to mate with corresponding Longeron attachment mechanisms.

In one embodiment, the attachment to the passenger bay is passive. In one embodiment, the attachment to the passenger bay is active. In the active embodiment, the cylindrical casing **8** is removable and/or deployable to another location. For example, the cylindrical casing **8** may be removed and placed in the International Space Station for a period of time. In one embodiment, the cylindrical casing may be removed and installed in another SSP Orbital Vehicle. In one embodiment, the cylindrical casing may be removed and attached to a Space Tug. In one embodiment, the cylindrical casing may be removed and attached to a booster rocket. In one embodiment, the cylindrical casing meets the specifications of CORE Section 4.2 Crew Module and Payload Habitable Volumes.

In one embodiment, the cylindrical casing may be removed and placed in a vehicle other than an SSP Orbital Vehicle. In one embodiment, the cylindrical casing may be removed and placed in a base on a distant planet. In the active embodiment, the mission may be longer than 14 days, depending on life support and other amenities available at the deployment location.

## The Shell Structure

In one embodiment, the cylindrical casing is encased in a shell structure adapted to provide a pressure and thermal barrier between the or more passengers. In one embodiment, the cylindrical casing **8** is encased in a shell structure adapted to prevent penetration of micrometeorites into the cylindrical casing **8**. In one embodiment, shell structure prevents atomic oxygen from degrading the space facing radiant properties. In one embodiment, the shell structure reduces the conductive flow of heat across the shell structure. In one embodiment, the shell structure provides a path for return air. In one embodiment, the return air acts as a working fluid for thermal control.

The thickness of the shell structure may vary with the dimensions of the other components of the cylindrical

## 6

casing. In one embodiment, the cylindrical casing combined with the shell structure has a combined outer diameter that fits in the payload bay. In one embodiment, the combined outer diameter of the cylindrical casing together with the shell structure is 86 inches.

In one embodiment, the shell structure is a layered structure. In one embodiment, the shell structure comprises three layers. In one embodiment, the total thickness of the shell structure is 3 inches. In one embodiment, the total thickness of the shell structure is about 3 inches or less. In one embodiment, the total thickness of the shell structure is less than 3 inches. In one embodiment, the total thickness of the shell structure is: about 2 inches or less; about 1.8 inches or less; about 1.6 inches or less; about 1.4 inches or less; about 1.2 inches or less. In one embodiment, the total thickness of the shell structure is about 1 inch or less. In one embodiment, the total thickness of the shell structure is 1 inch.

In one embodiment, the shell structure comprises an outer layer of fire resistant material. In one embodiment, the outer layer is a layer of beta cloth. Beta cloth comprises is a fireproof cloth made of fine woven silica fiber, similar to fiberglass. Beta cloth melts only at temperatures exceeding 650° C. In one embodiment, the betacloth is coated with TEFLON™ (tetrafluoroethylene) to reduce its tendency to crease or tear when manipulated, and to increase durability. Beta cloth is commercially available from Saint-Gobain Performance Plastics of Merrimack, N.H. doing business as Chemfab. In one embodiment, beta cloth is a fiberglass woven cloth impregnated with PTFE TEFLON™ (polytetrafluoroethylene) and contains no silicon to protect against atomic oxygen degradation. In one embodiment the outer layer has a thickness of: from about 0.1 to about 2 inches; about 0.2 inches or more; about 0.4 inches or more; about 0.6 inches or more; about 0.8 inches or more; 1 inch or more. In one embodiment, the outer layer has a thickness of about 1 inch. In one embodiment, the outer layer has a thickness of 1 inch. In one embodiment, the outer layer has a thickness of 1 inch or less.

In one embodiment, the shell structure comprises a middle layer comprising one or more lightweight, flexible metal sheet. In one embodiment, the lightweight, flexible metal sheet comprises one or more of the following materials: aluminum, lithium, and a blend thereof. In one embodiment the lightweight, flexible metal sheet comprises an Al—Li blend. Suitable Al—Li flexible metal sheets are commercially from Alcoa, Davenport, Iowa. In one embodiment the middle layer has a thickness of: from about 0.1 to about 2 inches; about 0.2 inches or more; about 0.4 inches or more; about 0.6 inches or more; about 0.8 inches or more; 1 inch or more. In one embodiment, the middle layer has a thickness of about 1 inch. In one embodiment, the middle layer has a thickness of 1 inch. In one embodiment, the middle layer has a thickness of 1 inch or less.

In one embodiment, the shell structure comprises an inner layer of insulation material. In one embodiment, the insulation material comprises one or more of the following materials: fiberglass, polystyrene foam, polyethylene foam, polyisocyanurate, and vacuum insulated panel. In one embodiment, the insulation material is fiberglass. Suitable fiberglass insulation materials are available from a variety of commercial sources. In one embodiment, the insulation material is fiberglass sheet material, commercially available as FIBERGLAS 700 Series, from Owens Corning of Toledo, Ohio. In one embodiment the inner layer has a thickness of: from about 0.1 to about 2 inches; about 0.2 inches or more; about 0.4 inches or more; about 0.6 inches or more; about 0.8 inches or more; 1 inch or more. In one embodiment, the

inner layer has a thickness of about 1 inch. In one embodiment, the inner layer has a thickness of 1 inch. In one embodiment, the inner layer has a thickness of 1 inch or less. The Passenger Bay Module

In one embodiment, the cylindrical casing **8** comprises a passenger bay module.

In one embodiment, the passenger bay module is adapted to transport and maintain habitable conditions for twenty or more passengers during a mission. In one embodiment, the payload bay is adapted to transport and maintain habitable conditions for thirty or more passengers during a mission. In one embodiment, the payload bay is adapted to transport and maintain habitable conditions for forty or more passengers during a mission. In one embodiment, the payload bay is adapted to transport and maintain habitable conditions for forty four passengers during a mission.

In one embodiment, the mission has a duration of: 30 days or less; 20 days or less; 14 days or less; 13 days or less; 12 days or less; 11 days or less; 10 days or less; 9 days or less; 8 days or less; 7 days or less; 6 days or less; 5 days or less; 4 days or less; or 3 days or less. In one embodiment, the mission has a duration of 2 days or more. In one embodiment, the mission has a duration of 3 days.

Referring to FIG. 2, the interior of the cylindrical casing **8** may have a variety of configurations. In the embodiment schematically represented in FIG. 2, the cylindrical casing encloses an upper passenger bay module **10**, a rear lavatory module **20**, and a service galley module **30** located below the passenger bay module **10**. In one embodiment, referring to FIG. 3, the passenger bay module **10** extends within the cylindrical casing from the lavatory compartment **20** to the ODS **40**. In one embodiment, the passenger bay module comprises at a proximal end the ODS **40**.

In one embodiment, referring to FIG. 4, the passenger bay module comprises a first substantially planar floor **50** extending from one side **51** of the cylindrical casing **53** to an opposed side **52** of the cylindrical casing **53**. In the embodiment illustrated in FIG. 3, the first substantially planar floor **50** is separated from and substantially parallel to the line (a) drawn between the first attachment trunnion **60** and the second attachment trunnion **62** in FIG. 3.

Referring to FIG. 3, the first substantially planar floor **50** extends longitudinally from an abutting face of the ODS **40** to an abutting face of the lavatory module **20**. In one embodiment, the first substantially planar floor **50** extends longitudinally from a bulkhead adjacent to an abutting face of the ODS **40** to a bulkhead adjacent to an abutting face of the lavatory module **20**. In one embodiment, the first substantially planar floor **50** divides the cylindrical casing **8** into a first substantially semicylindrical compartment and a second substantially semicylindrical compartment.

The first substantially planar floor **50** may be made of a variety of materials. Suitable materials include, for example, aluminum, aluminum-lithium, carbon-epoxy composite, plastic, and wood. In one embodiment, the first substantially planar floor **50** comprises a blend of aluminum and lithium. In one embodiment, the first substantially planar floor **50** is 2190 Aluminum Lithium, commercially available from Alcoa, Davenport, Iowa. In one embodiment, the substantially planar floor **50** comprises an upper surface comprising carpet or other floor covering.

In one embodiment, the substantially planar floor **50** is welded to the interior of the cylindrical casing **8**. When welding is referred to herein, the welding may be variable polarity plasma welding, friction stir welding, and/or fusion arch welding. In one embodiment, variable polarity plasma welding is used to weld the substantially planar floor to the

interior of the cylindrical casing. In one embodiment, the welding is commercially available from Advanced Manufacturing Engineering Technology, Rexburg, Id. In one embodiment, the weld is purged on both sides with argon and helium. In one embodiment, the weld comprises a filler metal. In one embodiment, the filler metal is derived from a welding rod comprising any suitable welding metal. In one embodiment, the filler metal comprises aluminum. In one embodiment, the welding rod is a 4043 aluminum welding rod. In one embodiment, the resulting welds pass x-ray tests and level three fluorescent dye penetration tests.

In one embodiment, the first substantially planar floor **50** is supported by a plurality of longitudinally extending support beams. The longitudinally extending support beams may have any suitable structure. In one embodiment, the longitudinally extending support beams are "I-beams," which are shaped like the letter "I."

In one embodiment, the first substantially planar floor **50** has a width of 174 inches. In one embodiment, the first substantially planar floor **50** is supported from beneath by four longitudinally extending I-beams **55a-55d**. In one embodiment, the longitudinally extending I-beams abut the first substantially planar floor **50** and extend longitudinally from a wall of the ODS **40** to the lavatory module **20**. In one embodiment, the longitudinally extending I-beams abut the first substantially planar floor **50** and extend longitudinally from a bulkhead **78** adjacent to the ODS **40** to a bulkhead **76** adjacent to the lavatory module **20**.

Referring to FIG. 8, a suitable I-beam support structure is depicted as comprising the four longitudinally extending I-beams **55a-55d** and the longitudinally extending keel I-beam **65**. In addition, the support structure also comprises a plurality of support arches.

In one embodiment, the support structure comprises one or more proximal support arches. In one embodiment, the support structure comprises one proximal support arch **300**. In one embodiment, second beams **300a, 300b** are welded to a first beam **300d**, which perpendicularly intersects and is welded to the proximal I-beams **55a-55d**. The second beams **300a, 300b** extend substantially parallel to one another from the first beam **300d** to distal ends welded to the interior surface of the cylindrical casing. In one embodiment, the proximal ends of the substantially parallel beams **300a, 300b** intersect the first beam **300d** at I-beams **55b** and **55c**, respectively. In one embodiment, a rounded arch beam **300c** extends between distal ends of the substantially parallel beams **300a, 300b**. In one embodiment, the rounded arch beam **300c**, runs adjacent to the cylindrical casing **8**. In one embodiment, the rounded arch beam **300c** is welded to an interior surface of the cylindrical casing **8**. In one embodiment, the rounded arch beam **300c** intersects and is welded to the keel I-beam **65**.

In one embodiment, the support structure comprises one or more aft support arches. In one embodiment, the support structure comprises a plurality of aft support arches **302** and **304**. In one embodiment, the support structure comprises two aft support arches **302** and **304** having similar structure. In one embodiment, referring to aft support arch **302**, the arch comprises a first beam **302d** perpendicularly intersecting and welded to the I-beams **55a-55d**. In one embodiment, substantially parallel beams **302a, 302b** of the support arch are welded to the first beam **302d** and extend substantially parallel to one another from the first beam **302d** to distal ends welded to the interior surface of the cylindrical casing **8**. In one embodiment, the proximal ends of the substantially parallel beams **300a, 300b** intersect the first beam **300** at I-beams **55b** and **55c**, respectively. In one embodiment, a

rounded arch beam **300c** extends between distal ends of the substantially parallel beams **300a**, **300b**. In one embodiment, the rounded arch beam **300c**, runs adjacent to the cylindrical casing **8**. In one embodiment, the rounded arch beam **300c** is welded to an interior surface of the cylindrical casing **8**. In one embodiment, the rounded arch beam **300c** intersects and is welded to the keel I-beam **65**. In one embodiment, the proximal and aft support structures meet the specifications of Section 3.3.1 of the CORE Orbiter/Payload Structural Attachments. In one embodiment, according to the Orbiter Coordinate System (OCS), the forward connection is at  $x_o=774$  in. In one embodiment, the aft connections are at  $x_o=1171.27$  in.

The I-beams may be made of a variety of materials. Examples of such materials include carbon-epoxy composite, titanium, aluminum-lithium, and aluminum. In one embodiment, the I-beams are aluminum I-beams. Suitable aluminum I-beams are commercially available from American Aluminum Extrusion (AAE) of Beloit, Wis. In one embodiment, the aluminum I-beams have a depth of 6.0 inches, a flange width of 4.0 inches, a web thickness of 0.210 inches, a flange thickness of 0.350, and a weight of 4.690 pounds per foot. In one embodiment, the aluminum I-beams are made 6061-T6 aluminum alloy.

In one embodiment, the passenger bay module **10** comfortably seats a plurality of passengers. In one embodiment, the passenger bay module comprises seats for from about 5 to about 44 passengers. In various embodiments, the passenger bay module comprises seats for: 5 passengers or more; 10 passengers or more; 15 passengers or more; 20 passengers or more; 25 passengers or more; 30 passengers or more; 35 passengers or more; 40 passengers or more; 44 passengers or more. In one embodiment, the passenger bay module seats 44 passengers.

In one embodiment, the seats in the passenger bay module **10** are upright. In one embodiment, the seats in the passenger bay module comprising a reclining mechanism. In one embodiment, one or more of the passenger bay seats recline to become substantially flat. In one embodiment, all of the passenger bay seats recline to become a substantially flat. The seats may be obtained from any Federal Aviation Administration (FAA) approved supplier. In one embodiment, the seats are obtained from Weber Aircraft, LLC, Gainesville, Tex.

Referring to FIG. 3, the seating arrangement in the passenger bay module **10** may have a variety of configurations. In the depicted embodiment, the passenger bay comprises three separate rows of seats. In one embodiment, side rows **12** and **14** extend longitudinally from the ODS **40** to the lavatory compartment **20** along opposite sides of the cylindrical casing **8**. As seen in FIG. 3 and FIG. 4, each side row **12**, **14** comprises two seats, an aisle seat **18** and a wall seat **19**. In one embodiment, a center row **16** of seats extends longitudinally from the ODS **40** to near the lavatory compartment **20** between the side rows. In one embodiment, the center row **16** comprises a row of single seats. In one embodiment, the center row **16** is separated from the side rows **12** and **14** by a distance of 15 inches.

As seen in FIG. 3, in one embodiment, the center row **16** comprises a single row of eight seats **17** extending from adjacent to the ODS **40** to a distance spaced from the lavatory module **20**. In one embodiment, referring to FIG. 5, the floor adjacent to the lavatory module **20** comprises a hatch **80** sealingly engageable with a port (not shown). In one embodiment, the hatch opens to permit a person to descend to a service galley module **30** located below the substantially planar floor **50**.

In one embodiment, the maximum inner diameter (width) of the passenger bay module is 174 inches. This inner diameter is nearly that of a Boeing 767 airliner, at 186 inches. In one embodiment, referring to FIG. 4, the first substantially planar floor **50** has a width (**82**) of 14 ft. 3 in. In one embodiment, the passenger bay module **10** has a broadest inner diameter at (**84**) of 14 ft. 6 in. In one embodiment, the passenger bay module covered by the shell structure **63** has an outer diameter at (**86**) of 15 ft.

In one embodiment, referring to FIG. 4, the outer length at **88** of the passenger bay module **10**, covered by the shell structure **63**, is 49 ft. 6 in. In one embodiment, the inner length **90**, from the ODP **40** to the lavatory module, is 49 in. In one embodiment, the lavatory module has a length (**94**) of 3 ft. 6 in.

The seats may have a variety of sizes and configurations. In one embodiment, for maximum space usage and comfort, each seat is situated within a space having a dimension of 3 ft by 5 ft.

The seats may be provided with a variety of amenities. In one embodiment, the seats are provided with one or more seatbelts. In one embodiment, the seats are provided with 4-point harness seatbelts. In one embodiment seats are provided with an overhead harness to facilitate ingress and egress. In one embodiment, the seats are provided with arm rests. In one embodiment, the arm rests are provided with cupholders. In one embodiment, the seats are provided with trays for meals. In one embodiment, the trays are retractable trays. In one embodiment, the retractable trays are retractable into the arm rest. In one embodiment, each seat is provided with a storage compartment. In one embodiment, each seat is provided with an in-seat entertainment system. In one embodiment, the seats are provided with one or more additional amenities.

In one embodiment, referring to FIG. 7, an upper surface **200** of the passenger bay module **10** comprises a plurality of sleeper cabins **202**. In one embodiment, from 1 to 5 sleeper cabins are provided. In one embodiment, the sleeper cabins are enclosed units that provide privacy. In one embodiment, the sleeper cabins **202** comprise the amenities provided for other seats located on the first substantially planar floor **50**. In one embodiment, the sleeper cabins **202** comprise upgraded amenities, for example, a DVD player or video game player, a hair dryer, and the like. In one embodiment, the sleeper cabins comprise a flat bed. In one embodiment, 5 sleeper cabins **202** are provided. In one embodiment, the sleeper cabins **202** have a length (**203**) of about 7.25 feet, a width (**204**) of about 5 feet and a height (**206**) of about 3 feet. In one embodiment, the sleeper modules are available at a higher price than other seats in the passenger bay module. In one embodiment, the availability of the sleeper modules, together with the number of total passengers and the number of flights run, renders operation in accordance of the SPP Orbital Vehicle as described herein financially feasible.

#### Power System

In one embodiment, the cylindrical casing **8** is provided with a power system. In one embodiment, the power system electronically communicates with the Space Shuttle Electrical Power Distribution and Control (EPDC) subsystem. In one embodiment, the power system comprises one or more battery power storage unit. In one embodiment, the power system comprises one or more lithium iron batteries. Suitable battery power storage units are commercially available from a variety of sources. In one embodiment, the battery power storage units are lithium iron batteries, commercially available from European Batteries of Tuusula, Finland.

## 11

For relatively short missions, the EPDC and the battery power storage unit(s) may be sufficient to meet power needs during the mission. In one embodiment, the SSP system is provided with supplemental externally mounted solar panels. In one embodiment, the solar panels also communicate with the EPDC system and augment the EPDC system, as needed.

In one embodiment, an electrical power interface is provided connecting the payload bay to the passenger bay module 10. In one embodiment, the electrical power interface is any suitable plug and cable/wire system. In one embodiment, the power system draws a possible 2600 Watts of power from the Space Shuttle as specified by CORE Section 7.0 Electrical Power Interfaces.

## The Service Galley Module

In one embodiment, referring to FIG. 4, the second substantially semicylindrical compartment is a service galley module 30. In one embodiment, the service galley module 30 communicates at a proximal end with the ODS 40. In one embodiment, the proximal end of the service galley module 30 communicates with the ODP, a port 66 extending from the ODS 40 into the service galley module 30.

In one embodiment, the service galley module 30 comprises a second substantially planar floor 57 spaced apart from and substantially parallel to the first substantially planar floor 50. In one embodiment, the distance between the second substantially planar floor 57 and the first substantially planar floor 50 is 5 feet 9.25 inch. In one embodiment, one or more longitudinally extending support structures 65 support the second substantially planar floor 57. In one embodiment, the one or more longitudinally extending support structure 65 is an I-beam. In one embodiment, the longitudinally extending support structure 65 is an aluminum I-beam.

In one embodiment, the service galley module 30 comprises a plurality of galleys accessible from a central access tunnel 67. In one embodiment, the galleys are separated by a plurality of bulkheads. In one embodiment, an initial bulkhead 74a is spaced approximately 10 feet from the ODP. In one embodiment, a second bulkhead 74b is spaced approximately 10 feet from the initial bulkhead 74a; a third bulkhead 74c is spaced approximately 10 feet from second bulkhead 74b; and, a fourth bulkhead 74d is spaced approximately 10 feet from third bulkhead 74c. In one embodiment, referring to FIG. 7, from 8 to 9 bulkheads 74 are spaced from the ODP 66 to the lavatory module 20. In one embodiment, a distal bulkhead 76 is located adjacent to the lavatory module 20. In one embodiment, the service galley module 30 abuts the lavatory module 20. In one embodiment, the service galley module 30 abuts the distal bulkhead 76 located adjacent to the lavatory module 20. The bulkheads also are seen in FIG. 7.

In one embodiment, the bulkheads separate one or more of the following galleys: a flight attendant galley; a pantry galley; a cargo galley; a life support galley; a storage galley; a fire detection and prevention galley; a module subsystem galley; and, a mechanical system galley. In one embodiment, the service galley module 30 comprises compartments comprising one or more of the following: a power system; a thermal control system; and, a backup system. In one embodiment, the service galley module 30 comprises one or more the following: a power system; a thermal control system; a backup system, and a combination of all of the foregoing.

In one embodiment, the service galley module 30 comprises combinations of the foregoing galleys. In one embodi-

## 12

ment, depicted in FIG. 4, the service galley module 30 comprises the following galleys spaced longitudinally along a first side 77 of the service galley module 30, in order from the ODP 66: a life support galley 100; a fire detection and prevention galley 102; a cargo galley 104; a pantry galley 106; and a storage galley 108. In the embodiment depicted in FIG. 6, the following aisle of galleys are spaced longitudinally along an opposed side 79 of the service galley module 30, in order from the ODP 66: a power system and thermal control galley 110; a backup systems galley 112; a cargo galley 114; the remainder of the pantry galley 116; and, a storage galley 118.

In one embodiment, the pantry galley provides one or more of the following: counters; heating appliances; water supply; disposal stations; and other galleys helpful in providing and serving meals and drinks, including water. In one embodiment, the pantry galley comprises one or more microwave oven. In one embodiment, the pantry galley communicates with one or more water supply.

In one embodiment, the hatch 80 (FIG. 5) and the ODP 66 (FIG. 6) comprise hatches that, when closed, provide an airtight seal. In one embodiment, the service galley module 30 provides a safe zone during an emergency or unforeseen event requiring additional protection of passengers. Such events might include, for example, an unknown approaching object and/or a solar flare. In one embodiment, the port 66 communicates with the service galley module 30 and may be sealed off. In one embodiment, the port 66 comprise external threaded grooves. In one embodiment, the port 66 is adapted to engage a hatch (not shown) comprising internal threaded grooves adapted to mate with the external threaded grooves on the port 66. Suitable hatches are commercially available from a variety of sources, including Westmore Engineering Ltd. of Northumberland, United Kingdom.

## The Lavatory Module

In one embodiment, the passenger bay module 10 is provided with a rotating lavatory module 20. In one embodiment, the distal end of the passenger bay module 10 abuts a rotating lavatory module 20.

The rotating lavatory module 20 may have a variety of configurations. In one embodiment, referring to FIG. 11, the lavatory module 20 comprises a relavator 600, a lavatory component 700, and a counterweight compensator 800 comprising a central shaft 810.

The lavatory component 700 rotates around the central shaft 810 in a first direction. The counterweight compensator 800 rotates around the central shaft in a direction opposite to the lavatory component 700. In one embodiment, the lavatory component 700 rotates around the central shaft in a counterclockwise direction and the counterweight compensator 800 rotates around the central shaft in a clockwise direction.

In one embodiment, the relavator 600 rotates around the central shaft in the first direction. In one embodiment, the relavator 600 rotates intermittently around the central shaft in the first direction. In one embodiment, the relavator 600 rotates intermittently around the central shaft in a counterclockwise direction.

In one embodiment, the lavatory component 700 comprises a lavatory central shaft 620. In one embodiment, the lavatory component 700 is adapted to rotate around the lavatory central shaft 620 in a first direction at a speed effective to produce a centrifugal force that replicates gravity. In one embodiment, the lavatory component 700 comprises a proximal lavatory wall, a distal lavatory wall, and a circumferential lavatory wall.

In one embodiment, the relavator **600** comprises a relavator central shaft **620**. In one embodiment, the relavator central shaft **620** extends longitudinally from the relavator **600** toward the passenger bay module. In one embodiment, the relavator **600** comprise a plurality of pie shaped structures **610a**, **610b**. In one embodiment, one or more of the pie shaped structures **610a**, **610b** is not solid. In one embodiment, one or more of the pie shaped structures **610a**, **610b** is solid. In one embodiment, all of the pie shaped structures **610a**, **610b** are solid.

In one embodiment, the pie shaped structures **610a**, **610b** comprise narrower internal ends in communication with the relavator central shaft **620**. In one embodiment, the narrower internal ends extend to wider circumferential relavator end surfaces **622a**, **622b**. In one embodiment, the pie shaped structures comprise a substantially planar relavator distal surface (not shown). In one embodiment, the pie shaped structures comprise substantially planar relavator proximal surfaces **624a**, **624b**. In one embodiment, the pie shaped structures comprise lateral relavator surfaces **626a**, **626b**.

In one embodiment, the pie shaped structures comprise a combination of substantially planar relavator distal surfaces (not shown), substantially planar relavator proximal surfaces **624a**, **624b**, and lateral relavator surfaces **626a**, **626b**.

In one embodiment, the lateral relavator surfaces communicate with the substantially planar relavator distal surfaces (not shown) and the substantially planar relavator proximal surfaces **624a**, **624b**. In one embodiment, the lateral relavator surfaces are substantially perpendicular to the substantially planar relavator distal surfaces (not shown). In one embodiment, the lateral relavator surfaces are substantially perpendicular to the relavator proximal surfaces **624a**, **624b**. In one embodiment, the lateral relavator surfaces are substantially perpendicular to both the substantially planar relavator distal surface (not shown) and to the relavator proximal surface **624a**, **624b**.

In one embodiment, the lateral relavator surfaces **626a**, **626b** define one or more "open" pie-shaped compartments between adjacent pie shaped structures. The open pie-shaped compartments may be substantially empty, or may be fitted to ease entry of a passenger into the lavatory compartment **700**. For example, the open pie-shaped compartments may be fitted with a substantially flat floor. In one embodiment, a substantially flat floor runs adjacent to the circumference. In one embodiment, one or more of the open pie-shaped compartments is fitted with an entry structure into the lavatory compartment. In one embodiment, one or more of the open pie-shaped structures is fitted with a "door." In one embodiment, the open pie-shaped compartments are empty.

In one embodiment, the substantially planar distal relavator surfaces (not shown) rotatably abut a proximal wall of the lavatory compartment (not shown). In one embodiment, the relavator **600** is adapted to rotate in the first direction around a line extending longitudinally through the relavator central shaft. In one embodiment, the relavator **600** is adapted to rotate in the first direction around a line extending longitudinally through the relavator central shaft **620** after receiving a rotate signal. In one embodiment, the relavator **600** is adapted to stop rotating around the line extending longitudinally through the relavator central shaft **620** after receiving a stop signal. In one embodiment, the relavator **600** is adapted to rotate around the line extending longitudinally through the relavator central shaft **620** in the first direction up to the speed of rotation of the lavatory compartment **700** around the same line, which also extends through the central shaft.

In one embodiment, the counterweight compensator **800** comprises a compensator central shaft **810**. In one embodiment, the compensator central shaft **810** extends longitudinally from a counterweight compensator backing **814** toward the passenger bay module **10**. In one embodiment, the counterweight compensator is adapted to rotate around the compensator central shaft **810** in a direction opposite the first direction. In one embodiment, a circumferential compensator wall extends from the compensator backing **814** to define a proximally extending compensator cup **812**.

In this embodiment, upon assembly, the compensator backing **814** rotatably abuts the distal wall **710b** of the lavatory component. In one embodiment, the compensator cup **812**, defined by the compensator circumferential wall **812**, extends proximally toward the passenger bay module **10**. In one embodiment, the compensator cup **812** rotatably externally abuts the circumferential wall **742** of the lavatory component **700**. In one embodiment, the compensator cup **812** rotatably externally abuts a circumference of the relavator, which includes the circumferential relavator end surfaces **622a**, **622b**.

In one embodiment, the lavatory **700** rotates at a speed effective to produce sufficient centrifugal force in the lavatory component to replicate gravity around a circumference of the laboratory component. In one embodiment, the counterweight compensator **800** rotates around the lavatory **700** at a speed effective to maintain a zero angular momentum of the entire system.

In one embodiment, the mass of counterweight compensator **800** is less than the mass of the lavatory component **700** but the counterweight compensator rotates faster than the lavatory component **700** to maintain the zero angular momentum of the entire system.

In one embodiment, the lavatory component **700** rotates in the first direction at a speed effective to replicate gravity. In one embodiment, the lavatory component **700** rotates in the first direction at a speed of from about 6 to about 47 rpm. In one embodiment, the counterweight compensator **800** has a mass less than the lavatory component **700** and the counterweight compensator **800** rotates in a direction opposite the first direction at a greater speed than the speed of the lavatory component **700**.

Knowing the mass of lavatory component **700** and the counterweight compensator **800**, persons of ordinary skill in the art are able to calculate appropriate rotation speeds to maintain a zero angular momentum of the entire system. In one embodiment, the lavatory **700** rotates in the first direction at a speed of 20 revolutions per minute and the counterweight compensator rotates in a direction opposite the first direction at a speed of 26.67 revolutions per minute. In one embodiment, the lavatory **700** rotates counterclockwise at a speed of 20 revolutions per minute and the counterweight compensator rotates clockwise at a speed of 26.67 revolutions per minute.

In one embodiment, a drive shaft assembly **900** (FIG. 12) controls the relative rotation of the components of the lavatory module **20**. In one embodiment, mechanical drive connections are provided by a flexible belt to efficiently transmit the rotational power between the electric motor and one of the rotatable shafts. In one embodiment, electric motors (not shown) located in the service galley provide the power to drive the relative rotation. Suitable electric motors are commercially available from a variety of sources. In one embodiment, the mechanical drive connections are provided by a set of gears working in tandem as a transmission to efficiently control the rotation of one of the rotatable shafts. In one embodiment the mechanical drive connections are

provide by a set of gears working in tandem as a transmission to efficiently control the rotation of all the rotatable shafts.

In one embodiment, the drive shaft assembly **900** comprises a stationary hollow central shaft **940**. In one embodiment, the compensator central shaft **810**, the relavator central shaft **620**, and the lavatory central shaft **720** extend at approximately a 90° angle from a back wall of the counterweight compensator **800** longitudinally toward the passenger bay module **10**.

In one embodiment, the central shafts **720**, **620** and **810** have a concentrically rotatable orientation around the stationary hollow central shaft **940**. In one embodiment, the lavatory central shaft **720** has a greatest diameter. In one embodiment, the relavator central shaft **620** fits concentrically and rotatably within the lavatory central shaft **720**. In one embodiment, the compensator central shaft **810** fits concentrically and rotatably within the relavator central shaft **620**. In one embodiment, the stationary hollow central shaft **940** fits concentrically within the compensator central shaft **810**. In one embodiment, ball bearings are provided in appropriate locations between the shafts in the drive shaft assembly to permit the load bearing relative rotation between the shafts. Suitable ball bearings are available from a variety of commercial sources. In one embodiment, the ball bearings are rolling element bearings, commercially available from RBC Bearings International of Oxford, Conn. In one embodiment, the ball bearings are aerospace plain spherical bearings that have a thin section. In one embodiment, the ball bearings have an unfixed outer and inner ring. In one embodiment, the ball bearings have an inner fixed ring. In one embodiment, the ball bearings have an outer fixed ring.

In one embodiment, a distal end **942** of the stationary hollow central shaft **940** engages with the interior of the cylindrical casing **8**. The engagement may be any suitable stationary engagement, for example, a threaded screw engagement, a bayonet engagement, a welded engagement, or other stationary connection. In one embodiment, the distal end **942** of the stationary hollow central shaft **940** comprises a bayonet connector that engages with a receiving bayonet connector at a distal interior surface **820** (FIG. **8**) of the cylindrical casing **8**. In one embodiment, the distal end **942** of the hollow central shaft **940** extends through and behind the compensator central shaft **810**.

In one embodiment, main structure connections **910**, **910b** are provided to stabilize a proximal end of the drive shaft. The main structure connections **910a**, **910b** may have a variety of geometrical configurations adapted to provide stability to the lavatory module **20**. In the embodiment of FIG. **12**, the main structure connections **910a**, **910b** comprise I-beams welded together to form an isosceles triangular support comprising an apex **937**, **950** where the two equal sides **913**, **915** and **918**, **920** form a 90° angle of an isosceles triangle. In one embodiment, the hypotenuse of the isosceles triangle comprises lower edges **914**, **916**. In one embodiment, two equal sides **913**, **915** and **918**, **920** of the isosceles triangles extend from the respective port and starboard ends of the lower edge **914**, **916** to the respective apex **937**, **950**.

In one embodiment, a proximal support **910b** and a distal support **910a** are provided. Referring to FIG. **12**, in one embodiment, a lower edge **916** of the distal support **910b** abuts and is welded to the substantially planar floor **50**. In one embodiment, the lower edge **914** of the proximal support **910b** runs substantially parallel to a distal face of the hatch **80**.

In one embodiment, a proximal end **937** of the stationary hollow central shaft **940** is engaged at an apex of the proximal support **910b** (FIGS. **10** and **12**). The engagement may be any suitable stationary engagement, for example, a threaded screw engagement, a bayonet engagement, a welded engagement, or other stationary connection. In one embodiment, the engagement at the proximal end **937** is a welded engagement.

The lavatory central shaft **720** is engaged along its length with the distal support **910a** (FIGS. **10** and **12**). The engagement may be any suitable rotatable engagement. In one embodiment, the lavatory central shaft **720** passes concentrically and rotatably through a cylindrical receiving shaft **950** at the apex **950** of the distal support **910a**. In one embodiment, the cylindrical receiving shaft **950** is welded to the apex of the distal main support **910a**. In another embodiment, a commercially available modified triangular main support is used. Suitable modified triangular main supports are manufactured from commercially available I-beams. In one embodiment, the hollow central shaft assists in providing air supply to the lavatory compartment by receiving air flow from a duct attached to the air supply plenum in the passenger compartment.

The operation of the lavatory module **20** will now be described. In one embodiment, referring to FIG. **9**, a passenger passes into a stationary lavatory entry **420** located at a distal end of the passenger bay module **10**. Referring to FIG. **10**, the stationary lavatory entry **420** communicates with the relavator **600**. In one embodiment, a door is provided between the stationary lavatory entry and the relavator **600**. In one embodiment, the door is a retractable door.

In one embodiment, the relavator **600** essentially comprises a rotating elevator that changes the passenger from a frame of reference of a non-rotating passenger bay module **10** to a rotating lavatory component **700**. The relavator comprises a plurality of opposed pie-shaped relavator compartments **510a**, **510b** separated by intervening pie-shaped separators **610a**, **610b**. In one embodiment, the relavator **500** comprises two opposed pie-shaped relavator compartments **510a**, **510b** separated by two pie-shaped separators **610a**, **610b**. The pie-shaped separators **610a**, **610b** may be made of any suitable material. In one embodiment, the pie shaped separators are made of plastic, aluminum and carbon-epoxy composite. In one embodiment, the pie-shaped separators comprise interior designed and engineered honeycomb, fiberglass, and plastic assemblies commercially available from Composites Unlimited of Irvine, Calif.

The relavator **600** rotates in a counterclockwise direction until a the electric motor operating the relavator receives a signal to permit entry of a passenger. The signal may be a variety of signals. For example, the signal may be generated upon sensing the weight in the entry to the relavator, by verbal command of a passenger, by pressing a button, or upon any number of active or automatic signals. In one embodiment, the passenger presses a button to stop the relavator. In one embodiment, the electrical engine operating rotation of the relavator communicates with the apparatus receiving the signal to stop rotation of the relavator.

In operation, a passenger passes into a stationary entry **420** (FIG. **9**), and a signal is generated to stop the relavator **600**. The passenger passes into one of the relavator compartments **510a** or **510b**. The relavator **600** begins to rotate counterclockwise. The counterclockwise rotation of the relavator **600** continues until the relavator is rotating counterclockwise at the same speed as the lavatory component **700**. At that point, the passenger is signaled to enter the



lavatory component. The signal may be communicated in a variety of ways, including, for example, verbally, using a beep or other noise, or having a port open. In one embodiment, the passenger operates a suitable opening mechanism to open a port (not shown) into a lavatory compartment **710a**, **710c**.

The lavatory compartments **710a**, **710b**, **710c** may comprise a variety of amenities. With reference to lavatory compartment **710a**, each lavatory compartment comprises a sink **740** and a toilet **760**. In one embodiment, the sink and toilet are located around the circumference of the lavatory compartment **710a**. In this embodiment, the rotation within the lavatory module **20** substantially replicates gravity, thereby assisting in maintaining fluids in the sink and/or toilet. In one embodiment, toilet **760** and the sink **740** are vacuum operated. Suitable vacuum operated toilets and sinks and are commercially available from a variety of sources, including Rogerson Aircraft Equipment Group of Irvine, Calif. In one embodiment, the lavatory compartment **700** comprises one or more water supply tank and one or more waste water tank (not shown). In one embodiment, the water supply tank(s) and the waste water tank(s) are plastic.

In one embodiment, a waste water supply tank is retained in a vacant compartment located between successive lavatory compartments. In one embodiment, a waste water tank is retained in the vacant compartment located between successive lavatory compartments.

In one embodiment, a waste water supply tank is retained in each vacant compartment located between successive lavatory compartments. In one embodiment, a waste water tank is retained in each vacant compartment located between successive lavatory compartments.

In one embodiment, the water supply tank(s) fluidly communicate with one or more sinks in one or more adjacent lavatory compartments. In one embodiment, a water supply tank(s) fluidly communicate with one or more toilets in one or more adjacent lavatory compartments.

In one embodiment, the waste water tank(s) fluidly communicate with one or more sinks in one or more adjacent lavatory compartments. In one embodiment, the waste water tank(s) fluidly communicate with one or more toilets in one or more adjacent lavatory compartments.

In one embodiment, the water supply tank(s) are adapted to fluidly communicate with an external source of fresh water, when present. In one embodiment, the waste water tank(s) are adapted to fluidly communicate with an external waste water retention tank, when present. In one embodiment, the water supply tank(s) and the waste water tank(s) are adapted to fluidly communicate with an external source of fresh water and an external waste water retention tank at docking station(s).

When the passenger is finished using the lavatory facilities, the passenger moves back from the lavatory into the relavator. In one embodiment, the passenger operates a signal to notify the relavator to stop. Once the relavator compartment **510a** or **510b** is located adjacent to the passenger's lavatory compartment **710a**, the passenger leaves the lavatory compartment **710a** and enters the relavator compartment, for example, **510a**. The relavator **600** then stops rotating, positioning the relavator compartment **510a** adjacent to the stationary compartment **420**. The passenger then exits the relavator **600** and the lavatory module **20**.

In one embodiment, the counterweight compensator **800** comprises a round planar backing **814** and a circumferential wall **815** extending from the backing toward the passenger bay module to form a cup structure. In one embodiment, the wall **815** has a width, indicated by the arrow sufficient upon

concentric engagement of the shafts **810**, **720**, and **620** to surround the lavatory module **700** and the relavator **600** around their circumference. In one embodiment, the wall has a width of 2.0 inch.

In one embodiment, the backing **814** and wall **815** of the counterweight compensator **800** may be constructed of a variety of materials. In one embodiment, backing and wall are constructed of alternating panels of carbon-epoxy composite. In one embodiment, the backing and wall are constructed of carbon-epoxy composite alternating with aluminum connectors. In one embodiment, the counterweight compensator is adapted to adjust components to compensate for inertia changes in the lavatory and relavator modules. In one embodiment, the counterweight compensator compensates for inertia along one axis. In one embodiment, the counterweight compensator compensates for inertia along two axes.

In one embodiment, the toilet is a vacuum flush toilet. Vacuum flush toilets are commonly used in passenger airplanes and do not require training for use. Suitable vacuum flush toilets are commercially available.

Life Support Systems and Integration

In one embodiment, the cylindrical casing **8** is provided with an Environmental Control and Life Support System (ECLSS). The ECLSS monitors and modulates a variety of parameters. In one embodiment, the ECLSS monitors one or more of the following parameters: cabin pressure; breathable oxygen levels; humidity levels; odors; and exhaled gases. In one embodiment, the ECLSS monitors all of the foregoing parameters. In one embodiment, exhaled gases monitored and modulated by the ECLSS include CO<sub>2</sub> levels. In one embodiment the ECLSS monitors and modulates nitrogen levels. In one embodiment, referring to FIG. **8**, the cylindrical casing **8** comprises one or more air ports **310a**, **310b**.

In one embodiment, the ECLSS units **402** are substantially the same as the Space Shuttle life support system units.

Referring to FIG. **9**, in one embodiment, the cylindrical casing comprises from 1 to 8 ECLSS units **402**. In one embodiment, the cylindrical casing comprises from 6 to about 8 units ECLSS units. In one embodiment, the cylindrical casing comprises 8 ECLSS units. In one embodiment, the ECLSS units are commercially available from Paragon Systems Inc., Tucson, Ariz.

In the embodiment of FIG. **9**, air supply and return headers are provided. The air supply and air return headers are ducts made of any suitable material. The ducts may have a variety of geometric structure, such as rectangular, triangular, cylindrical, and the like. In one embodiment, an air supply header and an air return header is provided on the port and starboard side in the service galley module.

In one embodiment, referring to FIG. **9**, a port header air return **404a** and a port header air supply **408a** are provided. In one embodiment, starboard header air supply (not shown) and a starboard header air return **404b** are provided. The port and starboard air return headers **404a**, **404b** communicate with the ECLSS units. The ECLSS units purify and humidify the air, as needed. The purified humidified air is then circulated within the cylindrical capsule **8** via the port air supply header **408a** and the starboard air supply header (not shown). In one embodiment, the port and starboard air supply and/or air return headers are provided with shut off valves. The shut off valves may be actuated in an emergency to shut off air flow from the service galley **30** to the passenger bay module **10**.

In one embodiment, referring to FIG. **9**, a port thermal return wall **406a** (cutaway) and a starboard thermal return wall **406** are provided. In one embodiment, used air from the

passenger bay module passes under the thermal return walls **406**, **406a** between a lower end **407** of the thermal return walls and the substantially planar floor **50** (not shown).

At an upper end, the thermal return walls comprise a passenger bay air circulation duct **412**. In one embodiment, air passes from the port air supply header **408a** and the starboard air supply header (not shown) through a proximal end of the passenger bay air circulation duct **412** and into the passenger bay module **10** through one or more openings in the passenger bay air circulation duct **412**. In the embodiment depicted in FIG. **9**, the air passes from the passenger bay air circulation duct **412** through one or more openings **414a**, **414b**, **414c** and into the passenger bay module **10**. The air circulates through the passenger bay module and under the thermal return walls **406**, **406a** to the port air return header (not shown) and/or the starboard air return header **404a**. The air then passes to the ECCLS units, where it is purified and recirculated via the port air supply header **404a** and the starboard air supply header (not shown).

In one embodiment, the passenger bay air supply duct also communicates with one or more sleeper air supply duct **410**. In one embodiment, one or more sleeper cabin air supply ducts **416a-c** extend from the sleeper air supply duct **410** directly to the sleeper cabins **202**. In one embodiment, one sleeper air supply duct **410** is supplied to each sleeper cabin. In this embodiment, the air from the sleeper cabins is returned to the passenger bay module **10**.

In one embodiment, the ECLSS maintains a pressure of about 14.7 psi and an air content of about 80% nitrogen/20% oxygen. In one embodiment, the air quality is maintained by passing the air in the closed system through canisters comprising metal hydroxide on a filter. The metal hydroxide may be a variety of materials including, for example, silver oxide, sodium oxide, potassium oxide, magnesium oxide, calcium oxide, or zinc oxide. In one embodiment, metal hydroxide is lithium hydroxide. In one embodiment, the filter has a pore size of from about 100 to about 500 microns. In one embodiment, the filter has a pore size of from about 200 to about 400 microns. In one embodiment, the filter has a pore size of about 300-microns. In one embodiment, the filter has a pore size of 300.

In one embodiment, the ECLSS performs from about 5 to about 15 air changes per hour. In one embodiment, the ECLSS performs from about 6 to about 14 air changes per hour. In one embodiment, the ECLSS performs from about 7 to about 13 air changes per hour. In one embodiment, the ECLSS performs from about 8 to about 14 air changes per hour. In one embodiment, the ECLSS performs from about 8 to about 10 air changes per hour. In one embodiment, the ECLSS performs approximately 8.5 air changes per hour. In one embodiment, the ECLSS performs 8.5 air changes per hour.

In one embodiment, the ECLSS provides air temperature control. In one embodiment, the ECLSS comprises a heat exchanger comprising plurality of independent loops effective to heat and/or cool the contained air. Suitable heat exchangers are commercially available from a variety of sources. In one embodiment, the heat exchanger is a component of Commercial Crew Transport-Air Revitalization System (CCT-ARS), commercially available from Paragon Systems of Tucson, Ariz.

In one embodiment, the ECLSS provides air humidity control. In one embodiment, the ECLSS comprises a heat exchanger slurper. The heat exchanger slurper adds moisture to or removes moisture from the air, as needed. Suitable heat exchanger slurpers are commercially available from a variety of sources. In one embodiment, the heat exchanger

slurper is a component of CCT-ARS, commercially available from Paragon Systems of Tucson, Ariz.

In one embodiment, the ECLSS provides odor control. In one embodiment, the ECLSS comprises a charcoal filter. Suitable charcoal filters are commercially available from a variety of sources. In one embodiment, the charcoal filter is a component of CCT-ARS, commercially available from Paragon Systems of Tucson, Ariz.

In one embodiment, the cylindrical casing **8** communicates with an internal oxygen supply tank (not shown). In one embodiment, the cylindrical casing communicates with an oxygen supply tank external to the space shuttle. In one embodiment, the cylindrical casing communicates with the oxygen supply for the crew of the SSP Orbital Vehicle.

In one embodiment, the cylindrical casing **8** communicates with the Atmospheric Revitalization System (ARS) of the SSP Orbital Vehicle.

In one embodiment, the life support system communicates with an oxygen supply tank internal to the passenger bay module. In one embodiment, the cylindrical casing **8** communicates with the Atmospheric Revitalization System (ARS) of the SSP Orbital Vehicle as specified by the CORE Section 6.3.1 as a typical habitable Space Shuttle module. Thermal Control

In one embodiment, a habitable temperature is maintained in the passenger bay module using any suitable thermal control system. In one embodiment, the thermal control system is a passive thermal control system. In one embodiment, heat or coolant is applied, as needed, at the interior and at the exterior of the passenger bay module by interfacing with the Space Shuttle Payload Active Cooling Kit (PACK) by flexible and rigid tubing segments as specified by CORE Section 3.3.5.2.1. In one embodiment, the passenger bay module will be separately insulated. In one embodiment, the interior of the passenger bay module is provided with insulation. Suitable insulation includes those described above. In one embodiment, the insulation modulates heat transfer. In one embodiment, the insulation provides acoustical damping.

#### 40 Various Specifications

In one embodiment, the cylindrical casing **8** and a SPP orbital vehicle comprising a payload bay **7** (FIG. **1**) loaded with the cylindrical cylinder **8**. In one embodiment, the cylindrical cylinder meets Program Description and Requirements Baseline, Program Definition and Requirements, NSS 07700, Volume I, Revision G, (Dec. 17, 1997) (copy provided, incorporated herein by reference) (hereafter, the "Space Shuttle Program Base Requirements").

In one embodiment, all welds in the cylindrical casing pass x-ray tests and level three fluorescent dye penetration tests, as described in the Space Shuttle Program Base Requirements. In one embodiment, the cylindrical cylinder **8** and a SPP orbital vehicle **2** comprising a payload bay loaded with the cylindrical casing **8** meet all of the structural, vibration, thermal, life support, and power systems specifications, as described in the Space Shuttle Program Base Requirements.

In one embodiment, the total weight of the cylindrical cylinder **8** and a SPP orbital vehicle **2** comprising a payload bay loaded with the cylindrical casing **8**, including passengers and cargo, meets the weight specifications of the Space Shuttle Program Base Requirements. In one embodiment, the dry mass of the cylindrical cylinder **8** and a SPP orbital vehicle **2** comprising a payload bay loaded with the cylindrical casing **8**, including passengers and cargo, meets the dry mass weight constraints of the Space Shuttle Program Base Requirements.

## 21

## Example 1

A mass estimate was prepared for a cylindrical casing having the foregoing construction. The results are given in FIG. 13.

Persons of ordinary skill in the art will recognize that many modifications may be made to the foregoing description. The embodiments described herein are meant to be illustrative only and should not be taken as limiting the invention, which will be defined in the claims.

We claim:

1. A space relevator adapted to transition an object between a stationary compartment and a rotating module rotating in a first direction, the space relevator comprising:

a relevator module comprising a plurality of substantially solid pie-shaped structures separated by a plurality of pie-shaped compartments, the plurality of substantially solid pie-shaped structures and plurality of pie-shaped compartments positioned around a central axis; and a relevator central shaft extending along the central axis; wherein the relevator module is adapted to receive a rotate signal and a stop signal, and wherein one or more of the pie-shaped compartments comprise an entry between the stationary compartment and the rotating module when the relevator module receives the stop signal and an entry between the rotating module and the relevator module after the relevator module receives the rotate signal.

2. The space relevator of claim 1 wherein the stationary compartment is a compartment of a space apparatus and the rotating module is adapted to be rotated at a speed that would be sufficient to produce centrifugal force in the rotating module to replicate gravity.

3. The space relevator of claim 2 wherein the rotating module comprises a lavatory component comprising a lavatory drum comprising a lavatory central shaft, the lavatory drum being adapted to continuously rotate around the lavatory central shaft in the first direction at the speed sufficient to replicate gravity, the lavatory drum comprising a proximal lavatory wall, a distal lavatory wall, and a circumferential lavatory wall.

4. The space relevator of claim 3, wherein the plurality of substantially solid pie-shaped structures comprise narrow internal ends adjacent to the central shaft and extend to wider circumferential relevator end surfaces, the substantially solid pie shaped structures comprising substantially planar relevator distal surfaces, substantially planar relevator proximal surfaces, and lateral relevator surfaces substantially perpendicular to the substantially planar relevator distal and proximal surfaces, the lateral relevator surfaces defining the pie-shaped compartments between the plurality of pie shaped structures, the substantially planar distal relevator surfaces rotatably abutting the proximal wall of the lavatory compartment, the relevator module being adapted to rotate in the first direction around the central shaft up to the speed of the lavatory drum upon receiving the rotate signal and to stop upon receiving the stop signal.

5. The space relevator of claim 3 wherein the relevator central shaft is rotatably nested around a stationary hollow central shaft and the lavatory central shaft is rotatably nested around the relevator central shaft.

6. The space relevator of claim 5 wherein the relevator central shaft is adapted (a) to increase the speed of the relevator module from a stationary position to the same speed as the rotating module, and (b) to decrease the speed of the relevator module from the same speed as the rotating module to the stationary position.

## 22

7. The space relevator of claim 6, wherein the first direction is a counterclockwise direction around the relevator central shaft.

8. The space relevator of claim 1 wherein the stationary compartment is a compartment of a space apparatus and the rotating module is adapted to be rotated at a speed that would be sufficient to maintain fluid in an open container.

9. A space relevator system adapted to transition an object between a stationary compartment and a rotating module, the space relevator system comprising:

the rotating module comprising a substantially cylindrical module adapted to rotate in a first direction around a central shaft extending along a central axis of the substantially cylindrical module at a speed that would be sufficient to produce a centrifugal force in the rotating module to replicate gravity;

a relevator module comprising a plurality of substantially solid pie-shaped structures separated by a plurality of pie-shaped compartments adapted to rotate around the central shaft in the first direction, the relevator module being adapted to receive a rotate signal and a stop signal, wherein one or more of the pie-shaped compartments comprise an entry between the stationary compartment and the rotating module when the relevator module receives the stop signal and an entry between the rotating module and the relevator module after the relevator module receives the rotate signal; and

a substantially cylindrical counterweight compensator adapted to rotate around the central shaft in a second direction opposite the first direction, the counterweight compensator comprising a counterweight distal wall extending from the central shaft to a circumference of the substantially cylindrical counterweight, the counterweight distal wall being independently rotatable relative to a distal wall of the rotating module.

10. The space relevator system of claim 9 wherein the stationary compartment is a compartment of a space apparatus and at least one of the relative weights or the relative rotation speeds of the rotating module, the relevator module, and the counterweight compensator are adapted to maintain a zero angular momentum of the space relevator system.

11. The space relevator system of claim 10 comprising a drive shaft assembly adapted (a) to increase the speed of the relevator module from a stationary position to the same speed as the rotating module, and (b) to decrease the speed of the relevator module from the same speed as the rotating module to the stationary position.

12. The space relevator system of claim 10 wherein the centrifugal force is sufficient to maintain fluid in an open container.

13. The space relevator system of claim 9 comprising a drive shaft assembly adapted (a) to increase the speed of the relevator module from a stationary position to the same speed as the rotating module, and (b) to decrease the speed of the relevator module from the same speed as the rotating module to the stationary position.

14. The space relevator system of claim 13 wherein at least one of the relative weights or the relative rotation speeds of the rotating module, the relevator module, and the counterweight compensator are adapted to maintain a zero angular momentum of the space relevator system.

15. The space relevator system of claim 9 wherein the rotating module comprises a lavatory component comprising a lavatory drum comprising a lavatory central shaft, the lavatory drum and lavatory central shaft being adapted to continuously rotate around the central shaft in the first

## 23

direction at the speed effective to replicate gravity, the lavatory drum comprising a proximal lavatory wall, a distal lavatory wall, and a circumferential lavatory wall.

16. The space relevator system of claim 15 wherein at least one of the relative masses and the relative rotation speeds of the lavatory drum, the relevator module, and the counterweight compensator are adapted to maintain a zero angular momentum of the space relevator system.

17. The space relevator system of claim 9 wherein the centrifugal force is sufficient to maintain fluid in an open container.

18. A method of using a space relevator to transition an object between a stationary compartment and a rotating module rotating in a first direction, the method comprising:  
 providing as the rotating module a substantially cylindrical module adapted to rotate in the first direction around a central shaft extending along a central axis of the substantially cylindrical module at a speed that would be sufficient to produce a centrifugal force in the rotating module to replicate gravity;  
 providing as the space relevator a substantially cylindrical relevator module comprising a plurality of pie-shaped solid structures alternating with a plurality of pie-shaped compartments, wherein the relevator module rotates around the central shaft, and wherein one or more of the pie-shaped compartments of the relevator module comprise an entry between the stationary compartment and the relevator module;  
 adapting the relevator module to receive a rotate signal and a stop signal;  
 transitioning the object from the stationary compartment into the entry after the relevator module receives the stop signal and is in a stop position;

## 24

sending the rotate signal to the relevator module to rotate the relevator module in the first direction until the relevator module is rotating at the same speed as the rotating module; and

transitioning the object from the entry into the rotating module.

19. The method of claim 18 further comprising providing as the stationary compartment a compartment of a space apparatus.

20. The method of claim 19 further comprising:

transitioning the object from the rotating module back into the entry;

sending the stop signal to the relevator module; and  
 transitioning the object from the entry into the stationary compartment once the relevator module is in the stop position.

21. The method of claim 20 wherein the relevator module rotates in a counterclockwise direction around the central shaft upon receiving the rotate signal.

22. The method of claim 18 further comprising providing a counterweight compensator rotatably abutting the rotating module adapted to continuously rotate in a second direction opposite the first direction around the central shaft, wherein the rotating module, the relevator module, and the counterweight compensator comprise a space relevator system.

23. The method of claim 22 further comprising maintaining a zero angular momentum in the space relevator system by adapting at least one of the relative weights or the relative rotation speeds of the rotating module, the counterweight compensator, and the relevator module to maintain the zero angular momentum of the space relevator system.

24. The method of claim 18 wherein the centrifugal force is sufficient to maintain fluid in an open container.

\* \* \* \* \*